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SCIENCE AND THE MECHANIC ARTS.

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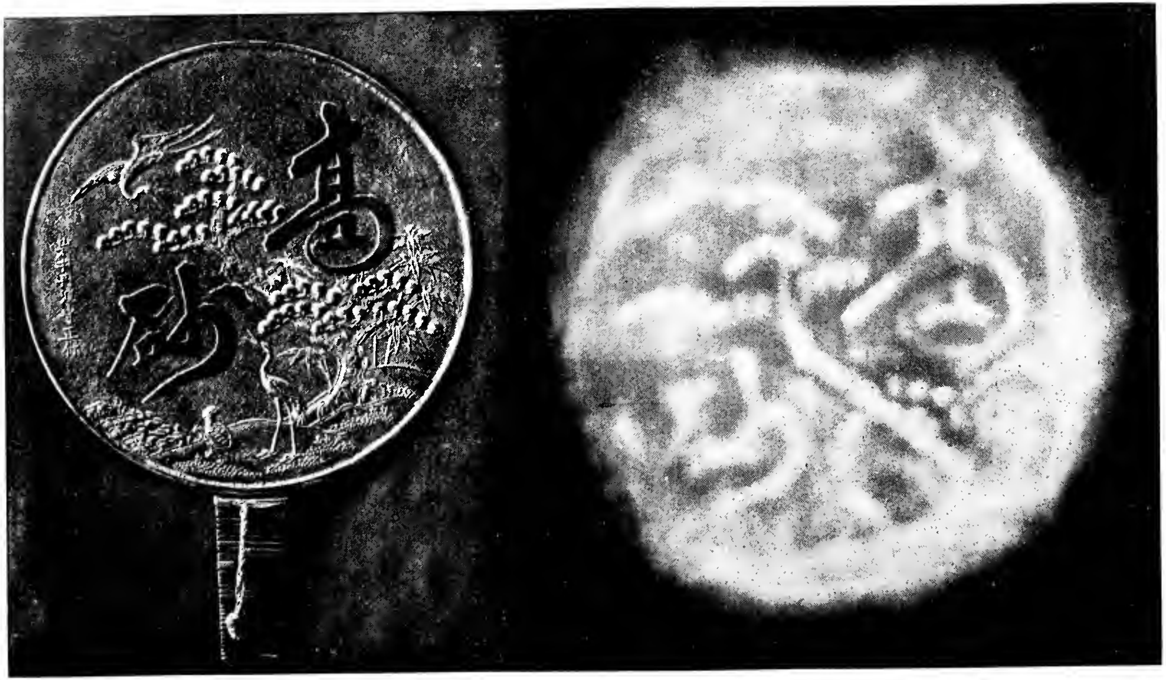

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THE JAPANESE MAGIC MIRROR.

JOURNAL

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FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXV. JANUARY, 1888. NO. I.

RAPID TRANSIT IN CITIES.

BY PROF. LEWIS M. HAUPT.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *November 11, 1887.*]

Professor Haupt was introduced by the Secretary of the INSTITUTE, and spoke as follows:—

Number is the basis of comparison. The usual method of expressing the value of an article is by affixing to it a number. Thus, whether the material welfare of a nation be measured by its tonnage, acreage, duties, population, or products, the measure or quantity of each must be expressed numerically. Moreover, it will be conceded that the value of all material products and even of the soil itself, depends upon the existence of man. It is not surprising then, since value is conferred by the presence of man, that population should be made a criterion or measure of material prosperity. Lord Bacon wrote: "The true greatness of a State

consisteth *essentially* in population and the breed of men." That this is true of communities, no less than of nations, does not require to be proven, and hence it is that the prosperity and development of a city are measured by the number of its inhabitants, and that its numerical strength is so jealously guarded.

But there are certain requirements of every community without which it cannot *increase;* it may exist and stagnate, as does a pond of water without inlet, outlet, or internal circulation, but it lacks the vitality of the living stream or lake, and must eventually evaporate.

Intercommunication is, therefore, essential to the development of a city, and the less restraint there is imposed upon a free circulation of mind and matter, the more rapid will be the accretion of knowledge and the increase of population. An acknowledged authority has stated that "rapid transit is the most important single question, no doubt, in any given city."

The fundamental queries before us, are then: What are the obstacles to locomotion in cities, and how may they best be removed or diminished?

The answers are, firstly, that any object which causes a divergence from the straight path joining the terminal points is an obstruction; and, secondly, our physical inability to move ourselves beyond a certain rate of speed, is likewise an impediment. Hence the difficulties in the way of rapid movements from place to place are of a dual nature; the one is external, as pertaining to the path; the other is internal, and inherent in the motor. Both, however, are susceptible of great modification, and the practical problem resolves itself into one of the relation of "the means to the end," or, more plainly, will it pay to make certain proposed modification in the ways of communication?

It will be seen at once, by a brief consideration of the process of development of a community, that the response to this important question is a function of the population, for, in the infancy of a city, when the settlement may have but a few hundred inhabitants, there are very few public improvements which would be justified and these only such as are necessary to support life, as for water, food, clothing, shelter, fuel and light, all of which may for a while be provided by individuals for their own or their families' use. But as the community increases there comes a time when it

is no longer profitable nor expedient for each family thus to provide for itself, and the work is delegated to others, specially appointed. Thus, in brief, the community becomes interdependent and there results an interchange of labor and commodities which must take place over certain channels, more or less direct, and when the population expands to a million or more it becomes a matter of vital importance to increase the facilities for transit correspondingly to prevent engorgement and suffocation from overcrowding, resulting in effeminacy, immorality, degeneracy and ultimate decay. This law is universal, and applies as well to communities as to individuals. If the circulation of a living organism is not maintained it dies. In the same manner if a healthy circulation in a community be impracticable it will lose vitality. The facility of movement when there is but one municipal centre should increase with the population; that is, with the built-up area. As the streets cannot, in general, be shortened, this result must be secured by increasing the velocity of movement. If population is wealth, then it is wise for a city to encourage a heathful growth and provide ready means of access to and from the commercial, manufacturing and financial centres. Hence the question before us is one of almost vital importance for the welfare of our city, and demands our serious and best consideration.

That the method of increasing the rapidity of movement by reducing the distance is the better one, will at once appear by observing that if the distance be diminished, there will result a decrease in time, space and power, cost, wear and tear and risks, while if the desired facility of movement be obtained merely by an increase of velocity, there must be an *increase* of cost, power, wear and tear and risk; the space remaining constant and the time only being reduced.

In a city laid out in squares it is quite possible to reduce the time of transit in certain directions by opening diagonal thoroughfares, and thus not only giving a greater available frontage for building, but bringing a large outlying area within the prescribed time limits.

The distance lost by going around the sides of a square is forty-two per cent. of that by the diagonal, and the waste of time and energy varies in the same ratio, so that our rectangular system of streets is open to serious objection from persons having to

traverse the city diagonally. In 1880, over sixty per cent. of the population lived beyond the limits bounded by Poplar Street, the Schuykill River, and Wharton Street; and the population within these limits had diminished 20,000 in ten years. To-day there are probably over 700,000 persons living beyond the limits mentioned, nearly all of whom, as well as those within the heart of the city, would be directly benefited by such a reduction of distance. The opening of the two main diagonal thoroughfares across this city would reduce the practical distance across by one and one-third miles and effect a saving, which in the aggregate seems almost fabulous.

The street-car travel is now about 125,000,000 per annum. If it cost but a half-cent per mile to transport each passenger, the saving of one mile would represent an annual saving of $625,000, or a capital of $12,500,000. The economy of time to the same number of pedestrians would be 3,565 years, and for those who ride say the half of this, or 1,783 years.

The work done by a man in walking one mile is taken at 33,120 foot-pounds, or about one-fifteenth of a horse-power, so that the energy saved in walking would be 8,333,333 horse-powers per annum.

The figures resulting from a saving of time by *increasing the velocity* are equally surprising when thus taken in the aggregate, as will be seen from the following extracts:

By doubling the velocity it is evident that for a given length of trip one-half the time is saved, so that the round trip requiring one hour, at street-car rate, would take but a half hour at the elevated rate of travel.

Thus a half hour would be saved for each passenger, and for the 125,000,000 this would amount to 62,500,000 hours, or 6,944,444 working days of nine hours.

A SURPRISING ESTIMATE OF WASTE OF TIME.

Taking 300 working days to the year, it would make 23,148 years. Startling as the result seems, it represents the amount of time which is actually sacrificed in this community each year by the *imperfection* of one of our ways of communication.

What is this waste of time worth? Taking the average value of the working day at only $2, it gives $13,888,888. These

figures explain very fully why it is that the public works of a city have so great an influence upon her material welfare.

In those cities which are readily accessible, and where the engineering works are commensurate with the requirements of the community, the increase in population has been very rapid. This is notably the case in many Western cities. In about three years Chicago will have surpassed us in population.

It may be said that such calculations are more curious than useful, but they are intensely practical, and represent facts which are none the less true because not generally observed. It is by recognizing these facts that the prosperity of a community is fostered.

The city also needs to be relieved from the dangerous obstructions and delays, caused by the passage of long lines of freight and passenger trains over and upon the streets at grade. In 1881, I collected the statistics of trains and passengers in and about the city, and found there were 22,000 train crossings per diem, which would amount to twenty per minute in a train day of eighteen hours, or one train upon twenty crossings every minute. This takes no account of the length of the trains, which may cover several crossings at the same time, nor of the rapidity of their movements.

The effect of an increase of velocity upon the available building area is shown by the following statement:

Before the introduction of the street cars in 1858, the built-up portion of Philadelphia covered less than seven square miles, or about five per cent. of its entire area; and during the next quarter century (to 1883) it had increased to but sixteen square miles, or to twelve and one-half per cent. There remained to be developed, therefore, eighty-seven and one half per cent. of the city's limits. The relative areas available, within a limit of half an hour, as affected by the kind and velocity of travel, are theoretically—

For pedestrians moving at the rate of two miles per half hour, 8 square miles.

For horse car moving at the rate of three miles per half hour, 18 square miles.

For elevated railroad moving at the rate of six miles per half hour, 72 square miles.

For underground railroad moving at the rate of ten miles per half hour, 200 square miles.

From this it will be seen that the revenue derived from assessment on real estate, other things being equal, will increase as the square of the velocity of travel.

But in applying these principles to Philadelphia, a reduction must be made for that portion of the salient angle cut off by the Delaware River, and the resulting areas become—

For pedestrians, 6¾ square miles or 5 per cent.

For horse cars, 13½ square miles or 10½ per cent.

For elevated roads, 50 square miles or 44 per cent.

For underground roads, 144 square miles or 112 per cent.

As in 1858, the city covered seven square miles, and in 1883, sixteen, it follows that in both instances it had outgrown the existing facilities of travel. (See *Plate I.*) Although this was proven to be true in 1883, still no material relief has been afforded since, and until it comes the city must relatively decrease in wealth and population. During the last decade the ratio of increase in Philadelphia (including West Philadelphia) was 2·4 per cent., while that of the latter district was 5·9, and of Camden it was 10·8, showing the direction of the movement in population to be along the lines of least resistance.

Marvellous as was the growth of travel in New York in 1884, it has continued rapidly to increase till at present it has outgrown the capacity of the existing plant, and projects are seriously contemplated which would lift the plane of traffic above the roofs of the houses by a series of long-span trusses resting upon tall iron towers, or depress it beneath the surface of the streets; or both methods may be applied as the demands increase. The increase in the elevated railroad traffic for 1887 was over forty per cent., being 158,963,232 passengers.

I have thus attempted to outline briefly the great necessity for, and some of the benefits to be derived from, increasing the facilities of communication, as well as the importance of the subject, and have stated the two general solutions of the problem. Let us now proceed to consider the several elements that enter into the acquisition of such facilities by the second method; viz.:

BY INCREASING THE VELOCITY OF TRAVEL.

At the present day, traffic is usually conducted on the surface, but it may be shifted to an elevated or a depressed plane, and since

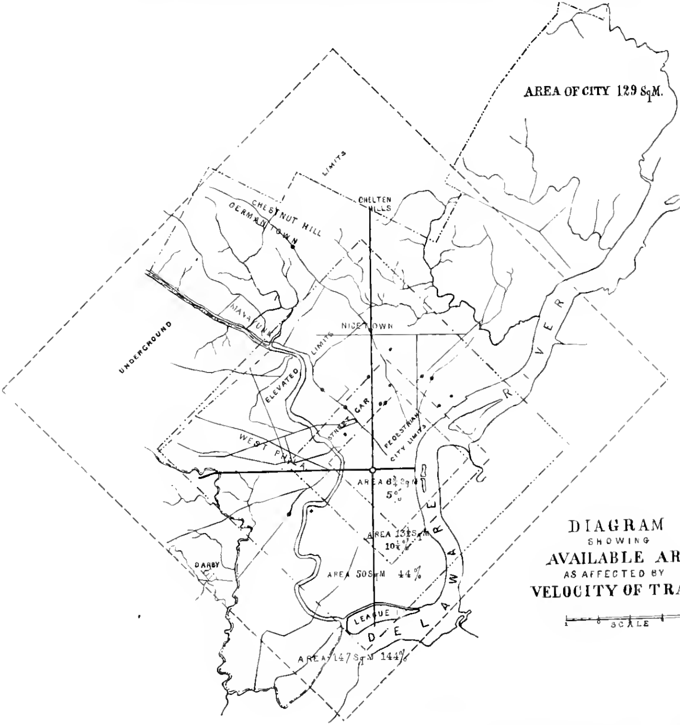

DIAGRAM
SHOWING
AVAILABLE AREAS
AS AFFECTED BY
VELOCITY OF TRAVEL

SCALE

the reasons for removing it from the surface are so manifest, I will merely consider here the relative merits of the elevated *versus* the underground plans.

The elevated structure would be in the air, and at a sufficient height to afford clearance for surface travel, which requires about eighteen feet. In cities it should be made to provide for the passage of extraordinary objects. It would be between the heights of the second and third floors of our buildings; its supports must extend into the streets, and would be something of an obstruction; there would be more noise than at present, less light in the buildings and streets below its grades, dangers from grade crossings of the elevated lines themselves; no relief to present surface travel, so far as concerns the number of vehicles and cars, and the structure could not, without considerable extra cost, be made to possess greater beauty than that arising from its utility and symmetry. Yet, notwithstanding these serious objections, some of which have been reduced to a minimum, if there were nothing else to offer, no city should hesitate to resort to such an expedient when the growth of its population is such as to warrant it. On the other hand, the underground system would pass through the earth, requiring artificial light, ventilation and drainage; its rails should be at twenty feet below the street surface to provide for the ordinary rolling stock of railroads; its patrons would see nothing of the city from the cars, and there would be the same danger from grade crossings as in the case of the elevated roads, but there are the additional direct advantages of less noise to residents, less dirt, no obstruction to light or to traffic of any description. It would furnish a means for relieving the surface of much of its travel; would facilitate the handling of freight; would be more permanent, and cost less to maintain, and would also confer upon the city the incidental benefits arising from having better pavements, requiring less expense to clean and maintain, and avoiding the necessity of continually breaking into them to lay or remove pipes, wires and conduits, which have grown to be so serious a matter. It would give better drainage and provide the sub-ways for all the city service along its route, which no elevated road can do; it would have a velocity sixty-six per cent. greater than that of the elevated road, and hence render about three times as much area available for habitation, within the same time limits; it would have much

greater capacity, both because of its increased velocity and by having four tracks instead of two, and it would pay an indirect annual revenue of great value to the city.

COMPARATIVE COST.

In regard to the relative cost of these two systems, I may say here that we are too apt to jump at conclusions, and to assume that because in general it is cheaper to build in air, than in earth or water, the underground would cost more than the elevated road. If this were the whole statement of the case it would be true, but if we are obliged to compare the cost of construction under the street with that through the second stories of buildings, there can be no question as to which will be the more expensive, and judging from the attitude of our citizens relative to the elevated railway ordinances, the latter condition represents very nearly the sentiment of the majority of the community, whose properties would be injuriously affected by the proposed elevated road.

The projectors of this city would have been more than ordinary mortals had they anticipated the requirements of two centuries, and yet but little departure has since been made in the widths and general plan of the streets, although the demands upon their capacity have enormously increased, and relief is urgently needed. The continual interruptions to travel and business, from the frequent laying of pipes, conduits, sewers, and house connections, are not the least of the inconveniences from which the community suffers. As a matter of municipal economy, it is desirable and expedient that the city should build subways for the better distribution and circulation of those essential elements which go to maintain a prosperous community. These are light, heat, power, water, sewage and sound all of which may be carried as fluids in underground conduits, and be distributed from central stations at much less expense than by the present system.

All things considered, therefore, the creation of a subterranean passage for quick transit of goods and merchandise, with avenues for conduits for fluids and for pneumatic tubes, may possess many and great advantages over the elevated lines.*

However desirable, necessary or beneficial a project may be, if

* The sentiment in New York, as expressed by her papers, is to the effect that *A Subway is the only Resource.*

it is to be carried out by private capital and enterprise, there must be a reasonable assurance of adequate return for the capital and labor invested, and sufficient guarantee that the policy of those authorizing and encouraging the work will remain constant for some definite period of time. In other words, it must appear that the work will pay, and that its projectors will be protected for a limited time from injurious competition.

This principle is recognized as essential to the success of all great undertakings. It was recently stated by one of the eminent judges of this city, that monopolies are evil in principle and become oppressive with age, yet a limited monopoly is essential to protect and encourage new undertakings. Our patent laws, which are based upon this principle, have done very much to develop the welfare of this country by securing to the inventor an absolute monopoly in his invention for a term of sufficient length to protect him from loss. This same principle must be recognized in the efforts now being made to develop the resources of the city by the use of private capital, and it may be plainly asserted that if franchises for the construction of rival lines are to be granted within short intervals of time, it will be many years before rapid transit becomes an accomplished fact in this municipality. Witness New York, where for years three rival companies have been competing and contending for the possession of subway privileges under Broadway.

Coming now to the question of cost and revenue, I will submit a somewhat detailed estimate of the probable expenses and receipts, as obtained from Mr. Jno. J. Deery, C.E., who has given much time to the details of the calculations for the Metropolitan Underground Railway Company, of this city.

ESTIMATED EXPENSES (*per mile*) FOR A FOUR-TRACK SUBWAY SIXTY FEET WIDE.

Earth excavation,	$124,893 00
Masonry in cement,	110,400 00
Concrete (1 : 1),	160,380 00
Bricks, including laying in cement,	103,660 00
Shoring,	30,000 co
I-beams,	135,327 45
Plates and blots,	6,358 08
Sixty-pound steel rails, angles, etc.,	44,136 00
Ties,	2,640 00

Dressed stone masonry,	$24,288 00
Asphalt,	32,313 60
Sewers,	22,000 00
Repaving with Belgian blocks of asphaltum,	34,546 50
Sidewalks,	10,558 80
Electric equipment, locomotive, cars, etc.,	122,000 00
Contingencies and engineering expenses, etc.,	96,350 14
Average cost per mile of covered subway,	$1,059,851 57

For the open-cut work, the estimated cost is $580,774.70.

REVENUES (*as per Estimate of the M. U. Ry. Co.*).

Earnings.—14,850,000 passengers, @ 7 cents,		$1,039,500 00
Section A. Four and one-eighth miles, cost,	$4,372,500 00	
Interest, @ 5%,	$218,625 00	
State tax on gross earnings,	8,316 00	
Operating expenses, sixty per cent.,	623,700 00	
		850,641 00
Balance (from passengers only),		$188,859 00

The estimated earnings are at the rate of $252,000 per mile.

In the matter of revenues it should be remembered that it is the long-distance rider who has the advantage, and that in New York the trains are filled at the terminals, leaving little or no accommodations for transient traffic. Thus the short rider is crowded out. In a city like Philadelphia, where the travel is in four directions instead of two, the proportions of short to long rides would be much greater and the revenues increased accordingly.

ESTIMATED REVENUE.

The receipts are based chiefly in such cases upon the number of passengers and the rate of fare, and it so happens that these elements are not hypothetical, but can be determined with considerable accuracy from experience in similar cases. Taking the case of the horse-car traffic as a basis, we find that during the year 1886, there were 128,185,698 passengers carried over the 329 miles of street railway track. This gives 389,622 passengers per annum to the mile, and furnishes one of the units required for the estimate.

The other elements are the unit of tributary area, unit of population, ratio of population to patronage, ratio of street-car to rapid transit travel, ratio of velocities and the rate of fare.

For the *unit of area* I take a strip one foot wide and one mile long, or *5,280* square feet; for the unit of population, the number of persons inhabiting an area of this size; from these the remaining factors are readily found.

According to the census of 1880, there was in the twenty-one wards composing the continuously built-up part of the city an average of 450 square feet of area* to each inhabitant; hence in a *unit* of area there would be *11·75* persons, which is the *unit of population*.

The width of the tributary area for a street-car line will be found by dividing the entire built-uparea by the total mileage within these limits, or eighteen square miles ÷ by 300, which gives ·06 miles, or only 316 feet, as the full average width of the area tributary to the street-car lines of this city, and it shows how admirably we are provided with this means of travel, and how narrow a strip of territory is required to maintain these lines with their unusually large dividends.

The *total population per lineal mile* for this tributary area is then 316 times 11 (omitting the fraction), or 3,476 persons. As before stated, *the traffic is 125 times the population*, and therefore the *patronage for each mile of street-car line* would be 3,476 times 125 = 434,500 persons per annum.

Comparing this computed result with that given from the statistics, as reported by the various companies, it will be seen that it is about 1·1 per cent. larger. This is then sufficiently close to verify the accuracy of the several elements which enter it as factors. We have yet to determine the relation between street-car and underground traffic as affected by velocity.

As in equal time intervals the areas are proportional to the square of the velocity, and as the average population varies directly as the area throughout the built-up sections; if the velocity of underground travel be twenty miles per hour, or three and one-third times that of surface travel, then the patronage should increase as the square of three and one-third, or be eleven times greater if all used the more rapid trains. As a matter of fact,

* Four hundred and thirty-five is the sanitary limit.

however, only a portion of the population do so ride. To determine this proportion, we may take the statistics from New York travel, for there the ratio of travel to population before the introduction of the elevated roads, was just about the same as in Philadelphia, viz., 125 times. It should be remembered, however, that the velocity is considerably less on the elevated than on the underground roads, and hence any deduction from the former will be below the limits, also, that since the construction of these increased facilities the ratio of travel to population has nearly doubled, being now 232 times. In taking the ratio of surface to elevated travel, therefore, from the New York statistics for last year, we should employ the corresponding ratio of total traffic to population. In 1886, the horse cars carried 210,039,484 passengers, and the elevated roads 115,109,591, making a total of 325,149,075, whilst the population was 1,398,931. The elevated traffic was then one-third of the total, or about eighty-two times the entire population.

Applying this ratio, then, we will have $3{,}476 \times 11 \times 82 = 3{,}135{,}352$ for the estimated number of passengers per mile for the rapid transit lines. That this is about equal to the actual patronage, as determined by experience in other cities, is seen from the subjoined statistics, giving density of traffic on rapid transit lines elsewhere.*

	No. of Passengers Per Mile Per Annum.
Manhattan (N. Y.) whole line (elevated),	3,552,000
Manhattan (N. Y.) Sixth and Third Avenues only,	4,215,000
The Metropolitan Railway, Berlin,	1,360,000
London Underground, Inter-Circle, 10·4 miles, estimated,	8,000,000
Metropolitan London Underground (whole line) 22 miles,	2,879,000
Metropolitan London Underground (District) 13 miles,	2,250,000
North London Underground,	2,680,000
Omitting the Inner Circle (estimated) the average is,	2,822,666
Average of all lines in England and Wales,	52,000
Average of all lines in United States (excluding elevated),	2,854

The entire annual traffic is then over 1,000 times that of ordinary railroad lines. The cost may, therefore, be greatly increased with the same prospect of dividends.

It also appears that the average passenger traffic is, in round

* *Railroad Gazette*, May 6, 1887.

numbers, 3,000,000 per mile, and that it is much higher in America than in Europe.

The second factor is the rate of fare. This on the Manhattan roads, where a five and ten-cent rate prevailed, as is proposed here, averaged, in 1886, 6·46 cents, and taking this as a basis it will give for the *gross receipts from passenger traffic only*, 3,135,350 × ·0646 = $202,543.61, which will represent a capital at five per cent., of $4,050,872.20 per mile. This is nearly four times the estimated cost of the line and it is based upon only one source of revenue. The receipts from rent of subways and from freight traffic, which would be conducted largely at night, would also be very large, so that the result we have reached would seem to guarantee an immediate return upon the capital invested, since there would be no need, as in a pioneer line of railroad, to wait for the population and development of the tributary areas.

It may be well to note here, for comparison, that the stock and bonded indebtedness of the Metropolitan Elevated Railway Company of New York, is stated in *Poor's Railroad Manual*, for 1886, at $34,318,000 or $1,055,000 per mile. The road was first opened for use in 1878 and has about reached the limit of its carrying capacity. The net receipts, in 1885, were forty-two per cent., while the last report of the Metropolitan (underground) Railway of London for the first six months of this year shows net receipts of over sixty per cent., or nearly $900,000.

This, too, in the face of the fact that in London the number of trips per inhabitant is only seventy-six, including all lines, and the rate of fare on the underground was but four cents.

London *Engineering* of February 19, 1875, says:

"In London the underground railroad system has been in operation for eleven years, and so great has been its success, so fully does it meet the requirements of the population, that every year adds to its extension. Opened in 1863, with a section of four and one-half miles, from Bishop's Road to Farringdon Street, it has been considerably extended, until now it has a length of about thirteen miles; while new extensions, costing some $12,000,000, are this year in progress of construction. Many millions of passengers are annually coveyed over these underground tracks, which extend beneath the streets in all directions, uniting the principal centres of trade, intersecting all the great railway lines,

and by the marvellous capacity for traffic, facilitating the enormous transactions of daily business, for which London is so renowned."

To further confirm the foregoing figures and to show that they are below the probable results, I quote further from the London *Railway News* a few statements of observed facts.

From the diagram,* *Plate II* (*Fig. 1.*), "it will be seen that before the Metropolitan (underground) line was opened, the London General Omnibus Company carried about 40,000,000 passengers annually. The average fare was seven cents and the cost to the company six and one-half cents per passenger. There was no marked increase in the business of the company until 1872, when, owing to the competition of the railways and tramways, a reduction in price was made. * * * The average fares by omnibus are now practically the same as by the railway, viz., about four cents. The London General Omnibus Company now carries very nearly as many passengers as the Metropolitan Railway, about 75,000,000 each. In regard to cost, however, there is a great difference, the expense per passenger by omnibus being about three and one-half cents, whilst by the railway the average is only one and one-half cents, although the latter spends $120,000 a year upon its road and contributes $160,000 to the local rates, whilst the omnibus is free from both these charges.

"In spite of the higher cost per passenger the omnibus is, however, able to pay twelve and one-half per cent., to its share-holders, whilst, owing to the enormous cost of the road, the railway company barely obtains a five per cent. rate. * * * On the tramway system, where there has of course been a much greater increase of mileage, the expansion in business has been about 100 per cent. On the tramways the average fare is about three cents, and the cost about two and one-half cents per passenger. In the twenty years from 1864 to 1884, the passenger traffic of the metropolis has increased 470 per cent., while in the same period the population rose only thirty-six per cent."

The sequel to this is that the traffic increases rapidly with additional facilities and without injury to existing tramways, so that an underground road will increase and not diminish the patronage of the existing surface lines. It will therefore be to the interest of the owners of the horse railroads to aid and

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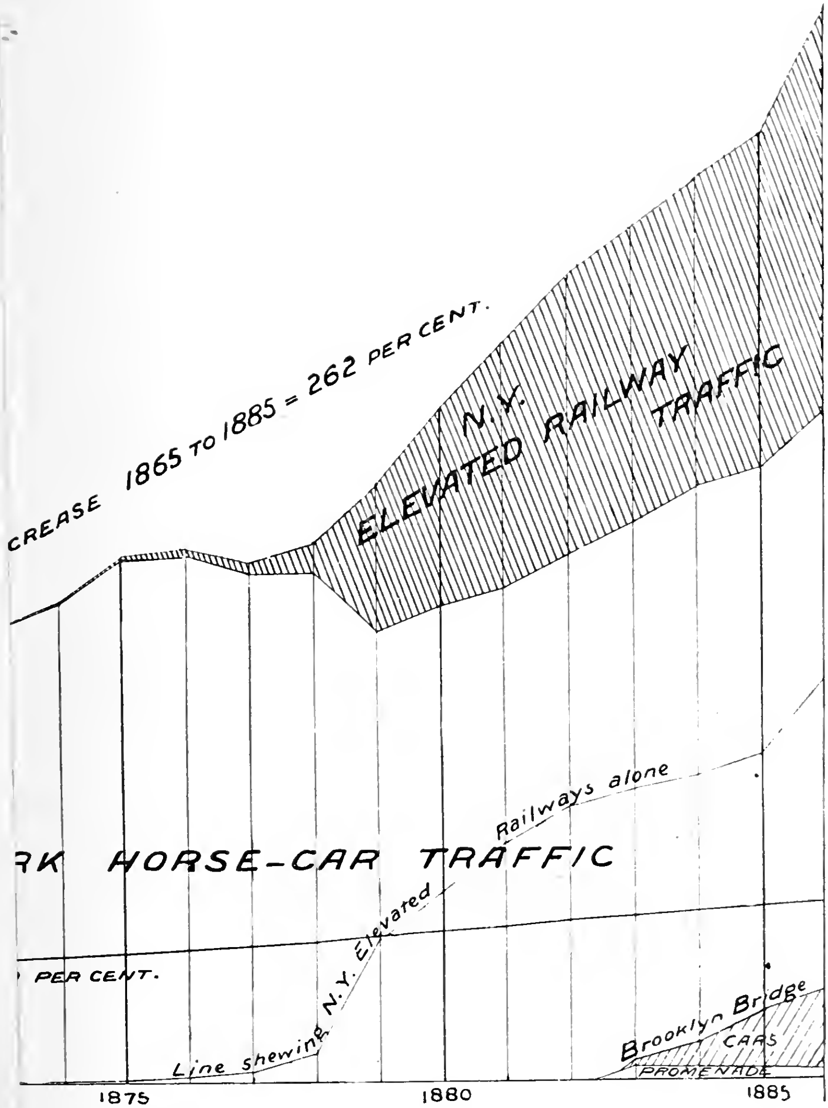
* Loaned to the JOURNAL by *Engineering News* of New York. See *Engineering News* of October 15, 1887.


CREASE 1865 TO 1885 = 262 PER CENT.
N.Y. ELEVATED RAILWAY TRAFFIC
RK HORSE-CAR TRAFFIC
Line shewing N.Y. Elevated Railways alone
PER CENT.
Brooklyn Bridge
CARS
PROMENADE
1875
1880
1885

to 1886.

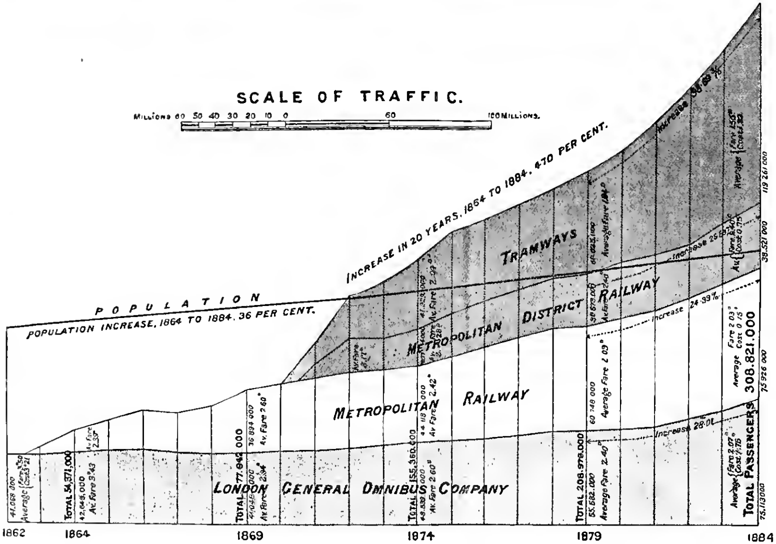


FIG. 1. City Passenger Traffic of London from 1862 to 1884.

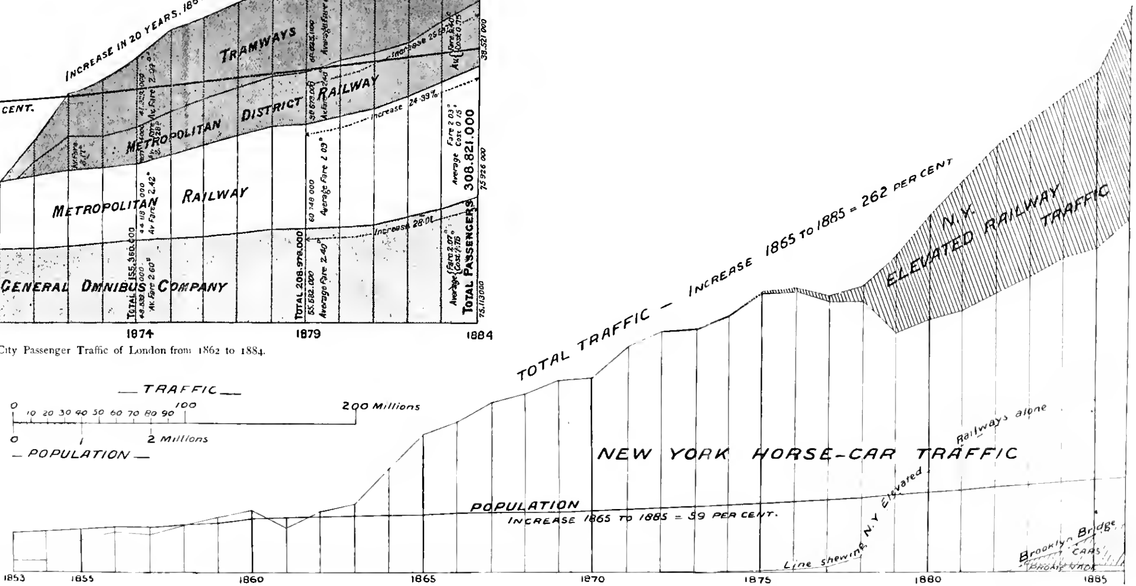


FIG. 2. City Passenger Traffic of New York from 1853 to 1886.

encourage the construction of underground lines, and thereby promote their own interests.

A similar development of traffic in New York is shown on the diagram,* in *Plate II* (*Fig. 2*).

CONFIRMATIONS.

The record of the Berlin Metropolitan Line contains some pertinent facts. For example: It was built by the Government; there was paid for the purchase of property, . . . $8,365,000
and for construction, ... 9,478,000

there was paid for the purchase of property,	$8,365,000
and for construction,	9,478,000
Total,	$17,843,000
Less sale of land, not used,	1,901,000
	$15,942,000
Length, 7·5 miles, cost per mile,	$2,115,000

It was an elevated masonry arcade. The cost of the right of way was nearly equal to that of the construction—or, deducting the receipts from sales of land, the expenditure for property was very nearly $862,000 per mile.

At the same rate in Philadelphia an elevated road would cost considerably more than one under ground. In an article on "Underground *vs.* Elevated Railroads," the *Railroad Gazette*, of February 18th, says:

"Coming now to the relative economy of construction above and below ground, we shall find that where both constructions have to buy their right of way, the underground would be the cheaper."

As a further check upon the estimate already submitted for the proposed Metropolitan Underground Road, I have looked up the cost of structures already built under nearly the same conditions, and find that the Union Tunnel, built in 1871–73, by the Pennsylvania Railroad Company, under the city of Baltimore, cost $247 per lineal foot, or $1,304,160 per mile. The material was clay, sand and rock. The dimensions were those generally used for double track, viz., 26 feet in width and 19½ in height. The excavation was let at $5 per cubic yard, and the masonry lining at $9 to $9.50. The total length was 3,402 feet and aggregate cost $840,000.

* Loaned by *Engineering News* of New York.

In the case of the underground road, in New York, known as the Fourth Avenue Improvement, provision is made for four tracks, two for express and two for way trains.

The work was authorized May 14, 1872, and the expense was to be divided equally between the city and the Harlem Railroad Company. To this end the city was empowered to raise the money by a special tax on real and personal property. The contract was executed and work was commenced late in the fall of the same year, with the firm of Dillon, Clyde & Co., for the sum of $6,395,070, for the four and one-half miles, or $285 per lineal foot.*

Of the entire distance from Forty-second to One-hundred-and-Thirty-third Street, one section of 6,937½ feet is open cut; one of 4,562½ feet is viaduct, and the remainder, 10,662 feet, tunnelling, or covered way. At the rate of $285 per foot, it would make the cost $1,504,800 per mile. This is for a section seventy-six feet wide in some places, and in which no provision is made for

* The various elements of this estimate are as follows:

	Total Amounts.
Earth excavation and embankment,	$579,000
Rock excavation in open cuts,	701,000
Rock excavation in tunnels,	255,000
Retaining walls,	1,013,000
Parapet walls,	100,000
Foundation walls,	238,400
Granite coping,	134,700
Plank in foundation,	70,000
Piling,	182,000
Concrete,	23,800
Removal of sewer gas water pipe,	300,200
Drain pipe,	6,800
Ballasting,	57,000
Brickwork in arches,	708,500
Blue stone,	34,300
Bridge from Seventy-ninth Street,	334,100
Iron bridges and approaches,	388,000
Wrought iron,	498,500
Cast iron,	23,500
Iron railing,	79,200
Felting,	36,500
Temporary track,	50,000
Ten per cent. for contingencies,	581,370
	$6,395,070

municipal service, and I believe I am correct in saying that no revenue is paid to the city, whereas the section proposed for the underground road here is but forty-eight and one-half feet for the four-track roadway, or about sixty feet, including the sub-ways, and but twenty-four feet for the two-track roadway, or thirty-two to thirty-four feet, including subways.

From these instances, it will be seen how large an amount of money these enterprising corporations felt justified in expending in depressing their tracks to sècure the benefits of more rapid movement and less risk in the cities through which they pass. The same policy at this terminal led the Pennsylvania Company* to elevate its tracks along Filbert Street, at a cost of $1,604,480 per mile for the nine track arcade, and it is now proposed to relieve the streets of Jersey City in a similar manner.

We may unquestionably infer then that the city would be amply justified in executing similar works as a part of her municipal improvements for the relief, safety, rapidity of movement and convenience of her citizens; or of aiding in such works by a liberal subsidy which would inspire the confidence of the community and so possibly enable the stock and bonds of the company to be taken at par by popular subscriptions. This would dispense with commissions and discounts, and would to that extent reduce the cost of the work, as well as remove the barrier placed in the path of progress by Senate Bill No. 249.

Such action would not only be expedient, but it would be fully warranted by precedent.

I have dwelt at considerable length upon this matter of "ways and means" rather than upon the the engineering questions involved, because it is fundamental to the success of any movement for the relief of the street traffic and the normal development of our city, and until the populace are satisfied that it is necessary and will pay, there is but little use in considering the mechanical details of the project. These are of secondary importance. It is only necessary to assure the incredulous that there is nothing chimerical or impossible in the engineering or construction

* The cost per lineal foot for the brick arches on Filbert Street, as given by Chief Engineer, Wm. H. Brown, Pennsylvania Railroad, was $266. The roadway is 108 feet wide and accommodates nine tracks.

features, and that the cost of executing them, I believe, would be such as to pay a fair dividend upon the investment.

With reference to the use of an iron superstructure for rapid transit, I beg leave to quote Mr. Wm. H. Brown, Chief Engineer of the Pennsylvania Railroad, to the effect that "there are no iron bridges built at the present time that will last more than ten or fifteen years under the present traffic."

It has now become the settled policy of the Pennsylvania Railroad Company to replace its iron structures by others of stone to reduce expenses of maintenance and increase the life of its bridges. The question of durability is one which has not received sufficient attention in the discussion between elevated and underground roads. To secure it, a masonry arcade on private property, passing through the middle of the block, would ultimately give the best results for an elevated project, but it would no doubt cost more than an underground road and give the city no direct service in subways, and their contingent benefit.

In the limited time remaining we can merely take a superficial view of the various solutions which have been presented for the problem of rapid transit, so far as they relate to the way, leaving out of consideration the rolling stock, motors, expenses of maintenance and operations, and numerous other items.

In conclusion, let us note what amount of territory is required per annum for a normal and healthful growth.

Every person brought into a community requires an average of 435 square feet for his healthful existence. This is at the rate of 100 individuals, or say twenty families to the acre. Deducting thirty per cent. for streets, it would give a lot of a size 18 x 87½ feet per family, which is certainly small enough. If the increase in population be taken at the rate of five per cent., we should have about 50,000 additional citizens a year,* or 10,000 families, requiring 517 acres, or nearly a square mile per year for the immediate future. Unless such an area is provided, a positive injury is imposed upon the individual as well as the community, and as there is no such available room within the already too densely settled built-up limits, the newcomers are obliged to find a habitat on the outskirts, and are subjected to the heavy indirect taxes resulting from loss of time and cost of transportation. This loss of time

* It is now about 20,000.

may soon reach a large percentage of the working day, and will prove in the future a greater barrier to growth than it has in the

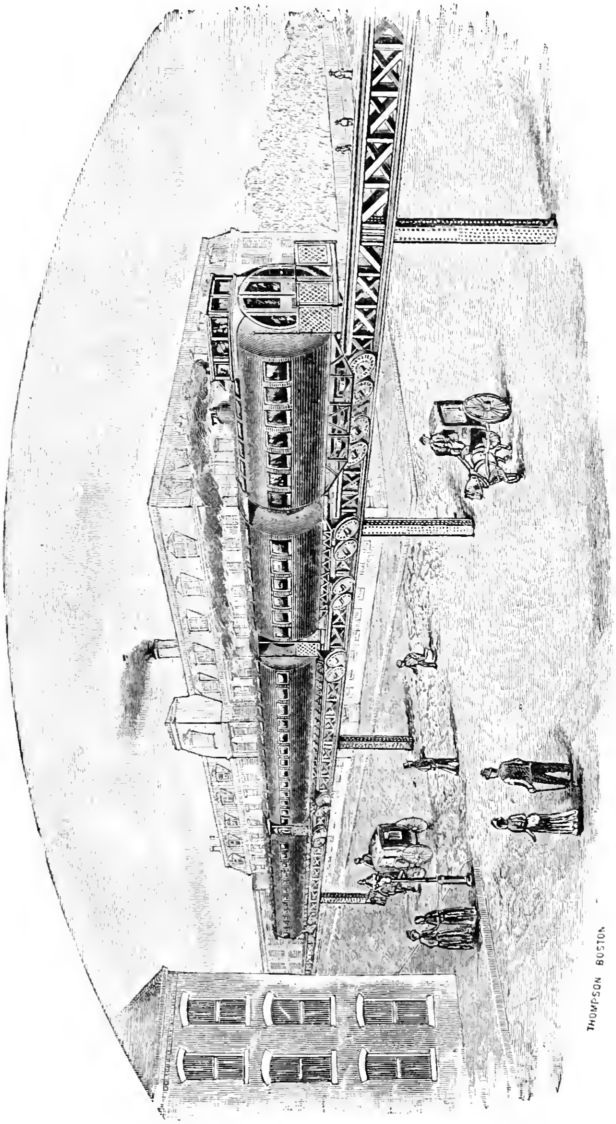


Plate III—The Meigs Elevated Railway.

past, unless the city will provide a means of transit more rapid than the jog-trot of the horse cars, and over a surface of less resistance than one paved with cobble-stones.

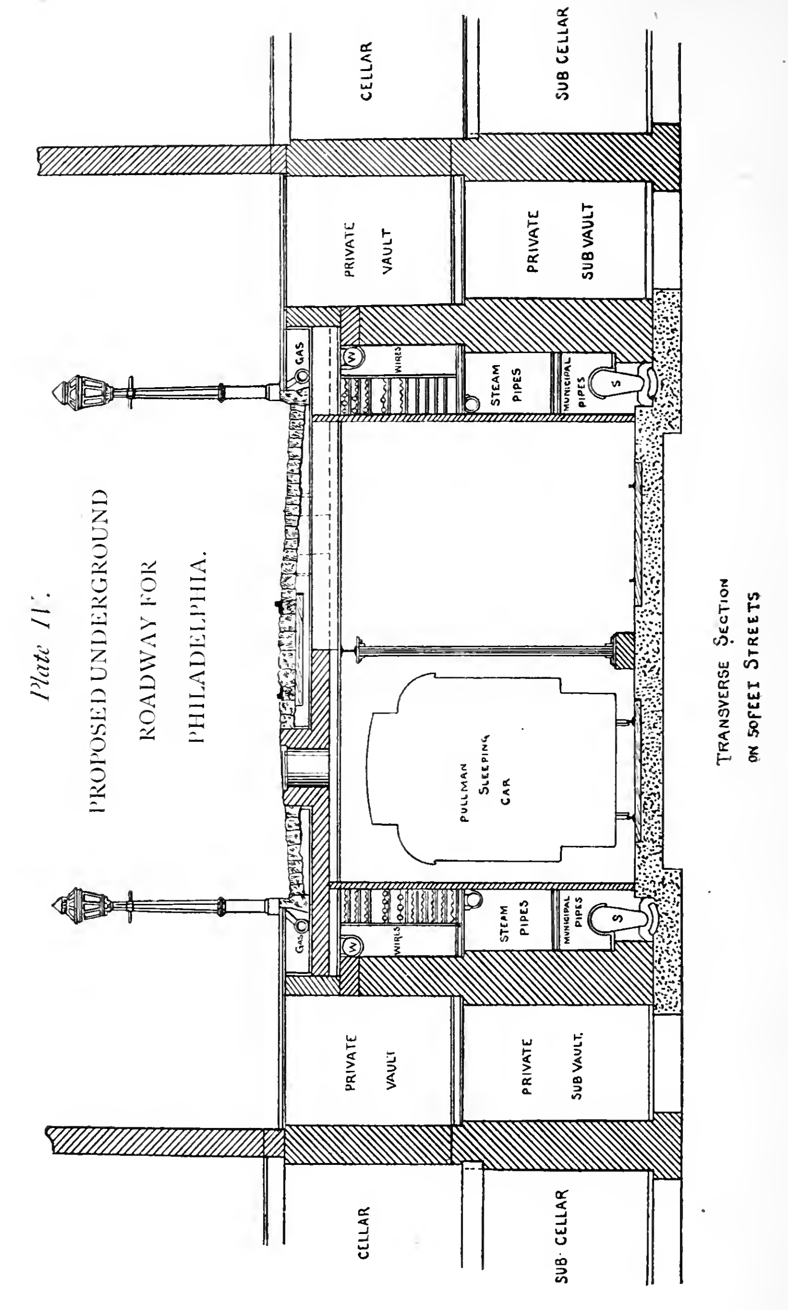


Plate IV.
PROPOSED UNDERGROUND
ROADWAY FOR
PHILADELPHIA.
CELLAR
SUB CELLAR
PRIVATE
VAULT
PRIVATE
SUB VAULT
GAS
W
WIRES
STEAM
PIPES
MUNICIPAL
PIPES
S
PULLMAN
SLEEPING
CAR
GAS
W
WIRES
STEAM
PIPES
MUNICIPAL
PIPES
S
PRIVATE
VAULT
PRIVATE
SUB VAULT.
CELLAR
SUB-CELLAR
TRANSVERSE SECTION
ON 50 FEET STREETS

NOTE.—The lecture was closed by the exhibition of the typical forms in use for elevated and underground roadways. Amongst these, special attention was called to the radical modifications made in the Meigs' Elevated System, as shown generally in *Plate III*, for which it is claimed that it can be built for $90,000 per mile, and that its trains can be run at a velocity exceeding sixty miles per hour, with almost absolute immunity from derailment. Amongst the underground projects exhibited and described, that for Philadelphia is shown in *Plate IV*.

The accompanying table is appended as a useful guide to determine at what periods a municipality should introduce additional traffic facilities to maintain a normal growth of five per cent.

Year.	City and County.	Percentage of Increase.	Persons to each House.	Built-up Area in Acres.	Area required at 100 to the Acre.	Computed Population compounded at 5 per Cent. per Annum.	Same at 2½ per Cent. per Annum.	Area required at 5 per Cent. Rate at 100 to the Acre.
					acres			acres.
1750	15,000	—	7·1	—	150·00	15,513	12,480	155·13
1760	18,756	25	6 6	—	187·56	25,269	15,974	252·69
1770	*29,444	57	6·5	—	294·44	41,137	20,446	411·37
1780	29,383	(—) ·2	5·3	600	293·83	66.971	26,170	669·71
1790	54,391	85	8·1	—	543·91	109,028	33,497	1090·28
1800	81,009	49	7·2	—	810·09	177,497	42,876	1774·97
1810	111,210	37	6·6	—	1112·10	288,965	54,881	2889·65
1820	135,637	21	6 6	—	1356 37	470,435	70,247	4704·35
1830	188,797	31	6 3	—	1887·97	765,868	89,916	7658·68
1840	258,037	36	4·8	—	2580·37	1,246,833	115,092	12468·33
1850	408,762[1]	58	6·7	2,200	4087·62	2.029,844	147,317	20298·44
1860	565,529	13	6·3	—	5655·29	3,804,586	188,565	33045·86
1870	674,022	19	6·0	—	6740·22	5,379,866	241,363	53798·66
1880	847,170	25	5·2	8,960	8471·70	8,758,421	308,944	87584·21
1890	—	—	—	—	—	14,258,709	395,448	142587·09
1900	—	—	—	—	—	23,213,178	506,173	232131·78
Averages,	—	35	6·3	—	—	—	—	—

* Computed.

1 City and County before consolidation, February 2, 1854.

As a matter of fact the ratio of growth decreases rapidly after the population exceeds half a million, unless rapid transit facilitie are introduced.

On SOME EARLY FORMS of ELECTRIC FURNACES.—

No. 1, PEPYS' ELECTRIC FURNACE.

By Prof. Edwin J. Houston.

The broad idea of utilizing the intense heat produced by powerful electric currents traversing conductors of comparatively high resistance, or of the even higher heat of the voltaic arc, for performing such metallurgical operations as require a high and yet readily regulable temperature, is quite old. The comparative ease with which such heat can be obtained in any required space, as well as the powerful chemical affinities of the terminals of a powerful electric source, led, at quite early dates, to the utilization of electric heat for furnaces. These early furnaces either combined electrical heat with heat of ordinary combustion, or employed the electric heat entirely separate from that of any other source.

The numerous ingenious applications that have recently been made of heat of electric origin, may render a brief reference to the early applications of electric heat to a few furnace operations not without general interest.

We therefore propose giving in successive issues of the Journal a brief notice of a few of the more interesting of these earlier electric furnaces.

When J. G. Children, F.R.S., was experimenting between 1809, and 1815, with his powerful voltaic batteries, he noticed, in common with other investigators, the intense heat he could readily obtain from electric currents.

At a meeting of the Royal Society of London, held on June 15, 1815, he gave an account of an interesting experiment in which Mr. Pepys established the now well known identity of chemical composition of the diamond and ordinary carbon. Pepys' demonstration of this identity was founded on the fact that a diamond, heated in contact with pure iron, under circumstances where admixture with foreign matters was prevented, converted the iron into steel. Such experiments had previously been made, but the certainty of the exclusion of carbonaceous materials, in the opinion of

many, had not been assured. Pepys therefore arranged the experiment in such a manner as to place such exclusion beyond all peradventure. The apparatus devised for this purpose constitutes one of the earliest electric furnaces.

The following description is taken from Vol. 105 of the *Philosophical Transactions* for 1815, p. 370.

"In the year 1796, M. Clouet converted iron into steel, by cementation with the diamond, with the view of confirming the nature of that substance, and of ascertaining the exact state in which carbon exists in steel. Clouet had previously formed steel by cementation with carbonate of lime. Mr. Mushet repeated this experiment, using instead of the carbonate, caustic lime, and obtained also what he considered to be cast steel: whence he concluded that the carbon necessary to cement the iron into steel had not been furnished as Clouet supposed, by decomposition of the carbonic acid, but that it had found its way from the ignited gas of the furnace to the iron. This result occasioned suspicions of the accuracy of the deductions from the experiment with the diamond: and Mr. Mushet accordingly, at the suggestion of the editor of the *Philosophical Magazine*, repeated the experiment made at the Polytechnic school, *only keeping out the diamond.* The results (for he made several experiments) uniformly gave him good cast steel, whence he concludes that we are still without any satisfactory or conclusive proof of the steelification of iron solely by means of the diamond." * * * * *

"It occurred to Mr. Pepys, that the battery would afford an *experimentum crucis* on the subject: and his ingenuity readily suggested a mode of making it, every way unobjectionable. He bent a wire of pure soft iron, so as to form an angle in the middle, in which part he divided it longitudinally, by a fine saw. In the opening so formed, he placed diamond powder, securing it in its situation by two finer wires, laid above and below it, and kept from shifting, by another small wire, bound firmly and closely around them. All the wires were of pure, soft iron, and the part containing the diamond powder, was enveloped by thin leaves of talc. Thus arranged, the apparatus was placed in the electrical circuit, where it soon became red hot, and was kept so for six minutes. The ignition was so far from intense, that few who witnessed the experiment, expected, I believe, any decided result—On opening the wire,

however, Mr. Pepys found that the whole of the diamond had disappeared: the interior surface of the iron had fused into numerous cavities, notwithstanding the very moderate heat to which it had been exposed; and all that part which had been in contact with the diamond was converted into perfect blistered steel—a portion of it being heated red and plunged into water, became so hard as to resist the file, and to scratch glass."

As will be seen the above is an excellent description of an electric furnace pure and simple. Bearing in mind the date of the publication it shows very considerable ingenuity.

CENTRAL HIGH SCHOOL.
Philadelphia, December 3, 1887.

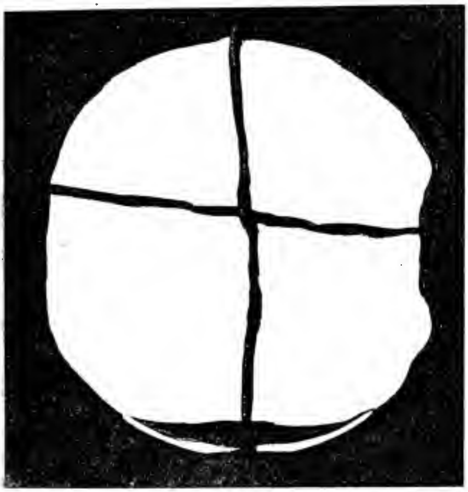
THE JAPANESE MAGIC MIRROR.*

The interesting apparatus, familiarly known by this name, is a circular, metallic, hand-mirror, having figures in relief upon its back. The reflecting surface is highly polished, and reflects the face as well apparently as mirrors of silvered glass; but when it is used to reflect the direct rays of a powerful light upon a screen, the reflection shows, with a moderate degree of distinctness, the figures that are at the back of the mirror. It is a popular belief that the cause of this phenomenon is unknown, and that the Japanese metal workers must have exercised a marvellous degree of ingenuity in the production of such a mirror.

Having recently had an opportunity to examine and experiment with one of these mirrors, I observed that it was slightly convex, and that when it was placed several feet from the eye, objects reflected in it appeared irregularly distorted, as if seen through a bad piece of common window glass. The conclusion arrived at was that there were irregularities in the convexity of the mirror quite sufficient to account for the striking irregular reflection of the sun's rays which is observed. It would be sufficient, in order to reproduce the figures at the back of the mirror, to have its face very slightly less convex on those parts, and such a condition may readily have been produced by means incidental to the quick and economical production of a metallic hand mirror.

* The substance of remarks made at the Stated Meeting of the Institute, held November 16, 1885.

The mirror is thin, the metal very elastic, and the general form of the back is slightly convex, measured by the top of the ornamental relief figures and rim. It is evident that if, in the operation of grinding the face of the mirror, it was held against the grinding surface by a flat support at the back, the pressure would flatten it until the ornamental relief figures rested upon the support, and on those parts the mirror would offer a positive resistance, and be ground away rapidly; but the thin parts between the relief figures having no direct support, would be sprung back by the grinding pressure, and would, therefore, be ground away less rapidly. On removal of pressure, the back of the mirror would



Reflection of Window Bars.

regain its original form, but the face, ground away irregularly, and most where the relief at the back was greatest, would have a slight but irregular convexity greatest on the thin parts between the relief figures.

The Japanese mirror appears to have exactly such a surface as would be produced in this manner. And if so, we should expect that upon springing the mirror flat by pressure, the polished surface would become plane again, and the figures vanish from the reflection. This experiment has been tried, the pressure having been applied by means of a heavy piece of plate glass, with the result anticipated. A photograph of the reflection has also been

compared with the back of the mirror, without discovering any peculiarities that seem to me inconsistent with this explanation. (*See Frontispiece.*)

Sir David Brewster made the first recorded attempt to explain the action of the Japanese mirror, suggesting that the design on the back was reproduced on the face by careful engraving, so lightly done that the figures traced are invisible after the mirror is highly polished, and can be made apparent only by using the mirror to cast a reflection of the direct rays of a powerful light.

Another and favorite theory is that the differences in the surface of the mirror are molecular, the metal having been rendered more dense, either upon or between the relief figures, by hammering, or by a peculiar method of casting, and that the denser parts reflect either more or less light than the rest. An English brass finisher claims that by stamping brass three times with the same die, and grinding and polishing after each stamping, a molecular difference is established, which produces this result. Even if this be true (which I doubt) such an explanation would not apply to the Japanese mirror, which gives an irregularly distorted reflection, as well as an irregularly lighted one. Irregular distortion cannot occur unless the reflecting surface is irregular, because it is a law of nature that the angle of reflection of a ray of light is always equal to the angle of incidence.

One writer, seldom quoted, did go so far as to attribute the irregularity of the reflection to irregularities in the convexity of the mirror, but supposed those irregularities to be due t oa process of stamping, hammering or chiselling. Mr. James Prinseps, in an article in the *Journal of the Asiatic Society*, vol. i, p. 242, makes the following interesting statements:

"The metal is highly sonorous when struck as a bell, and is so soft as to be indented or scratched on contact with any hard surface. I found its composition to be: Copper, eighty parts; tin, twenty parts; with no traces of silver or arsenic, and a very slight indication of zinc."

* * * * * * * * * *

"I believe the true explanation is suggested by the well-known phenomenon of the reflection from a brass button, which every school-boy has remarked when sporting his Sunday 'blue coat with metal buttons' in the sunshine of his tutor's parlor window. The

button throws a radiated irregular image on the wall, exhibiting two bright concentric circles, one on the edge and another about one-third within it, and there is generally a bright spot in the centre; all of this seems but the picture of the stamp on the back of the button; the radii resemble, and, indeed, coincide with, the letters of 'superfine' or 'trebly gilt' inscribed within a double circle, and the central spot represents the shank. There can be little doubt that the principle is in this case precisely that of the Japanese mirror; and, on a cursory view, its surface looks equally smooth and unsuspicious. On a minute examination, however, of several buttons, I found them to be by no means plane; their general surface is slightly convex; there is a hollow in the centre and a projection in the position of the inscription behind, caused no doubt by the blow necessary in stamping it. The polish is probably given by a rotary motion, and consequently does not remove these very small irregularities. To follow up the experimental investigation, I selected one of the buttons which gave a good image, ground it on a flat bone, and polished it; all the magical figures vanished in a moment, and a plain, bright disc appeared in their stead. Here, then, may be a key to the mystery of the mirror; the deception is entirely produced by irregularities in the surface, which are rendered the less perceptible to the eye, because the surface is convex instead of being plane."

* * * * * * * * * *

"It follows from analogy that the thin parts or tympanum of the Japanese mirror are slightly convex with reference to the rest of the reflecting surface, which may have been caused either by the ornamental work being stamped or partially carved with the hammer and chisel on its back, or, what is more probable, that part of this metal was by this stamping rendered harder, so that in polishing it, it was not worn away to the same extent."

The mirror we have here is 9 inches in diameter, $\frac{1}{8}$ of an inch thick at the rim, and from $\frac{1}{2}$ to $\frac{2}{3}$ as thick between the relief figures. It appears to have been cast and not stamped, hammered or chiselled. It is my belief that it was produced in the simplest manner possible, by casting, grinding and polishing. It is at least certain that such a result, as we have here, must follow such a procedure as I have described, and for the reasons I have stated. Engraving, stamping, hammering and chiselling would be alike

superfluous. It follows, that the magical feature of the first Japanese mirror may not have been, and probably was not, produced intentionally, and that our former estimate of the Japanese metal-workers' ingenuity may be taken *cum grano salis.*

F. E. Ives.

The ETHER-OXYGEN LIME LIGHT.

By F. E. Ives.

[*Read at the Stated Meeting of the* Institute, *Wednesday, December 21, 1887.*]

The vapor of sulphuric ether has been found to give as good results as coal gas in the production of the lime light. As first employed for this purpose, the ether was vaporized by heat, but this method has always been regarded as troublesome and unsafe. Mr. S. Broughton, of England, tried to improve upon it by dividing the oxygen supply and passing a small portion of it through liquid ether, where it became charged with ether vapor, which it then conducted to the hydrogen side of the jet. There were several objections to this method: the oxygen could not be perfectly saturated with ether vapor in this way, and in a cold room or with impure ether there was always danger of the flame retreating into the saturator; if this occurred, it was almost certain to either burst the saturator and throw the burning liquid about the room, or to force it back into the oxygen holder and produce a still more dangerous explosion. The passage of the gas in bubbles through the liquid also caused the light to flicker so badly that I imagine few operators would have tolerated it. Mr. Broughton sought to overcome the first objection by packing the mixing chamber of his jets with granulated pumice, through which the flame will not readily retreat; but this made it almost impossible to use the light at all in two lanterns, connected through a dissolving key, and, of course, did not stop the flickering. Serious accidents resulted from the use of the wash-bottle saturator, and it was abandoned, after creating a general impression that ether could not possibly be employed with safety. Mr. Broughton afterward used a saturator in which the oxygen was passed over the liquid ether instead of through it, and so stopped the flickering,

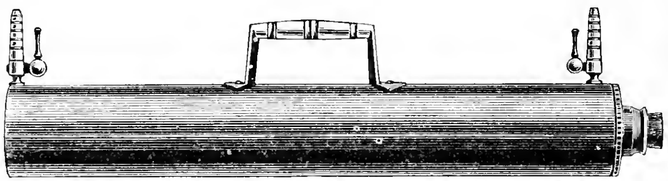
but did not publish this method for some time. The first published improvement on the wash-bottle saturator was invented and patented by me in 1882. It consisted of substituting for the wash bottle a chamber packed with a porous material, which was saturated with the liquid ether and so arranged that the oxygen was charged with vapor without bubbling through the liquid. This saturator was also provided with a removable cap, which permitted the porous filling to be removed and dried out whenever it became overcharged with the alcohol and water that is always present in commercial sulphuric ether. With this saturator, the oxygen can be perfectly saturated with ether, and is then absolutely non-explosive; the light is also perfectly steady, and can be used with perfect success for dissolving, provided that the jets have small tubes and mixing chambers, and the dissolving key a proper adjustment. It is also absolutely safe, if properly connected with the lantern and oxygen supply, because even with an explosive mixture in the saturator, it is impossible to produce an explosion that will either damage it or throw out liquid ether. As originally placed on the market, this saturator was provided with removable rubber caps, for which the present owners of the patent have substituted a metallic screw cap, which is made to fit ether-tight by applying common bar soap to the screw thread.

The ether light, as produced with this saturator, is now employed by some of the best known lantern operators in the country, who are enthusiastic in its praise; but in spite of the success and enthusiasm of many, there are some to-day who affect to believe that its use ought to be prohibited as dangerous, and others who are either too stupid or too "smart" to manage it successfully. Members of the FRANKLIN INSTITUTE have had ocular demonstration of its success and convenience, as it has been used in illustrating most of the INSTITUTE lectures during the past year; but its greatest advantage lies in the extreme compactness and portability of the requisite apparatus. I will take the liberty to reproduce here some endorsements of the light by well-known men who have used it. Prof. Wm. A. Anthony says:

"With the same pressure of oxygen, the ether light is better than the hydrogen. * * * In the qualities of steadiness, freedom from noise, etc., it is certainly equal to any lime light, and in convenience of manipulation, especially for a travelling exhibition, it is far superior to either hydrogen or house gas."

Dr. John Nicol says: "I have been closely identified with lantern work since 1853, and have used and experimented with almost every method of illumination and every variety of apparatus that has been introduced or suggested, and have no hesitation in saying that the production of an oxy-hydrogen light of the very highest class is obtainable with this saturator with absolute safety, and with less trouble than by any other device or apparatus that I have seen."

Notwithstanding the great success of this means for producing the lime light, and the important advantages which it offers, I have always recognized in it certain minor faults, which I hoped to overcome in course of time, and my object in preparing this paper has been to call attention to some recent improvements I have made, which I believe will greatly extend the use of the light, and increase its popularity. The first improvement is in the construction of the saturator, which is reduced in size, yet increased in



effectiveness. The second is in the use of petroleum ether (rhigolene), which gives the same light as sulphuric ether, but vaporizes at a lower temperature, costs much less, and contains neither alcohol nor water to accumulate in the saturator.

My improved saturator is in the form of a single metallic tube, 2 inches in diameter and 13 inches long, with a handle at the middle and a stop-cock projecting upward at each end. A neck, like that of a bottle, projects from the screw cap at the end, and is closed with a cork for convenience in filling. The passage for oxygen is over twenty inches long, in the form of a zig-zag channel through the upper surface of the roll of porous material, and secures complete saturation of the gas with vapor. This saturator can be filled from a bottle in one minute, and is ready for use at once, or may be kept filled for any length of time. It will supply a pair of lanterns, connected by dissolving key, for two hours, continuously.

Petroleum ether costs only thirty cents a pound, which is less than half the price of sulphuric ether. It should be stored in a cool place and kept tightly corked. It is also necessary, when using it with oxygen from a cylinder, to use a valve that can be opened very slowly, because a very small amount of oxygen passing through the saturator will produce a very large flame at the jet; the Shaw valve, manufactured by Mr. Shaw, a member of this INSTITUTE, fulfils the requirements, and is already largely used in this city. Some special instructions for the management of the light in hot weather may also be called for. Upon opening the saturator stop-cock in a warm room, a small amount of ether will vaporize spontaneously, and should be allowed to escape at the jet before turning on the oxygen supply; before the light has been run a minute, the vaporization will have become perfectly regular.

In conclusion, I give it as my opinion that this improved means for supplying the hydrogen element is so much simpler and more convenient than any other, that it cannot fail to entirely supersede the use of hydrogen and coal gas when its merits shall have become generally known and appreciated.

THE REACTION OF A LIQUID JET;

Being a Review of § 522 and § 523 of Weisbach's „Ingenieur- und Maschinen-Mechanik, Erster Theil; Fünfte verbesserte und vervollständigte Ausgabe, Braunschweig, 1875;"
With some additional matter.

BY PROF. J. BURKITT WEBB, Stevens Institute, Hoboken, N. J.

(*Concluded from Vol. cxxiv, page 473.*)

In the first part of § 522 Weisbach states clearly that the phenomenon of reaction concerns the water in the vessel "flowing towards the opening," and he introduces his analysis with the statement: "In the following manner we arrive at a knowledge of the complete reaction of the outflowing water." It ought not to seem inconsistent with this that the analysis itself says nothing about the water in the vessel, but considers it only in the acts of entering and of leaving the same, because quite complicated phenomena are very often governed by such simple and general laws that the complications may be ignored and a result obtained

in a simple manner; besides he does not say "a complete knowledge," but "a knowledge of the complete reaction." But when we consider that the assumption usually made in this problem, that the water enters the vessel in lines parallel with its axis and leaves it parallel to the axis of the jet, is not true in most actual cases and that its motion through the vessel may be a complicated one, it becomes pertinent to inquire how far the equations given apply to such cases and, also, whether the way in which the water flows through the vessel can have any effect on the result. We need, therefore, a *more complete knowledge of the reaction, both completed and incomplete.*

The following considerations will serve to complete our knowledge of the completed reaction. When the water passes through any section, as G, with a velocity not at right angles thereto, such equations as (7) are not true, but become so by putting the component of the velocity perpendicular to the section in place of the velocity itself. Such equations, however, as (5), (9), (11) and (13), expressing the relations between heads, velocities squared and energy, are unaffected by the change if we give a suitable meaning to α; thus in (11), etc., α must be the angle between the velocities c and v. The "2" in the denominator of (19) is a misprint. On the contrary, equations like (7) are not affected by the fact that in actual cases a part of the energy of the flow is continually being dissipated in a vibratory form, as sound, heat, etc., while equations between heads and velocities may require considerable modification on this account.

It has also been assumed that the velocity is constant throughout any section; when it is variable, the whole flow must be divided into elementary streams, for each of which the formula will then apply, and the whole reaction will be had by integrating the differential reactions of these streams or jets. If the elementary streams or jets are not parallel, then to obtain the total reaction in any direction, the components of their reactions in that direction must be integrated. The reaction, then, in any direction of the most complicated jet is simply the momentum per second of the same in the contrary direction.

If we desire a more complete knowledge of the incomplete reactions, *i. e.*, if we wish to know how the water acts before the change from the entering to the issuing jet is complete, including

the effect of a complicated motion within the vessel, we proceed as follows:

When a liquid flows through a pipe of varying section, the velocity of its particles is forced to change, and if the particles move in curved paths centrifugal force is developed; both of these actions affect the pressure on the pipe. The following simple analysis, which I have not, however, seen elsewhere, shows that these actions are in perfect agreement with the principles already developed.*

In *Fig. 9*, $g f$ is an "elementary stream," e and e' are sections of the same and move with it, they are not necessarily at right angles to its axis, but are at a distance apart equal to $v\,d\,t$. The whole stream may be supposed to be divided into elements of this length, in which case each element will, during each interval of time $d\,t$, advance into the exact place previously occupied by the one before it, and will change its length and section correspondingly. The volumes of all such elements will be $q\,d\,t$, and their masses $\delta\,q\,d\,t$, where q is the quantity per second flowing in the elementary stream, and δ the mass per cubic foot, v is the velocity of the element $e\,e'$, and makes with the co-ordinate axes the angles α, β, γ, whose cosines are a, b, c, so that the component velocities in the three directions are $v\,a$, $v\,b$, $v\,c$.

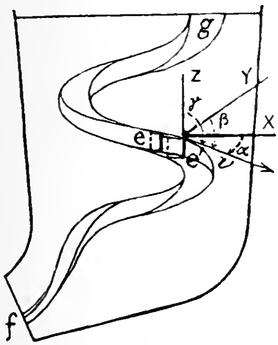


FIG. 9.

It is unnecessary to distinguish between accelerating and centrifugal forces, and we may put at once for the total accelerating force in the x direction

$$X = \Sigma \text{ elementary masses} \times \text{their accelerations}$$

$$= \int_g^f \frac{d\,(v\,a)}{d\,t}\,\delta\,q\,d\,t = \delta\,q\,(v_2 \cos \alpha_2 - v_1 \cos \alpha_1)$$

where α_1 and α_2 are the values of α at g and f_1; we shall have also

*A demonstration for an elementary stream confined to a plane may be found in „Die Physik von Dr. Alb. Mousson, 1879"; elementary streams, however are rarely so confined.

similar formulæ for Y and Z. From these we see that the most complicated motion of the water in the vessel creates only such variations in the pressure of the water as balance themselves on the vessel, thus a whirling motion may cause an equal outward pressure on all sides of the vessel, while it leaves the effect upon the vessel as a whole equal to the difference of momenta per second of the issuing and entering jets, *Q E D*.

Two models have been designed and constructed by the author for the experimental determination of the reaction of a liquid jet. One of these was intended to give only a rapid approximate measure of the reaction and to be suitable for demonstrating the subject before a class, where a continuous flow of water cannot be had; the other requires such a flow, and gives accurate results. Weisbach concludes § 495 with a description of experiments by Mr. Peter Ewart, in which the reaction of a horizontal jet was weighed; this experiment is, however, much simpler than the measurement of the reaction of vertical and inclined jets. In describing the models, such variations from the actual apparatus will be introduced as may be necessary to make the essential construction more quickly apparent, or as would be evident improvements—such as the substitution of a transparent tube for the tube of brass now in the model—and some minor details may be omitted.

Fig. 10 shows the first model in elevation and plan. It consists of a light glass tube A, 2 inches in diameter and 24 inches long, with brass ends B B; the upper piece B is a simple flanged collar, while the lower contracts to a nozzle F of $\frac{5}{16}$ of an inch bore. A light vertical shaft C runs the whole length of the tube, and carries a valve D on its lower end; a small rotation of the shaft is enough to slide the valve over the opening F and it is brought to rest in the proper position, and at the same time forced up tight against F by meeting an inclined plane formed by the bent wire E; the spring H tends to close the valve.

To the upper piece B is screwed a piece I which serves to support the different pieces of the upper mechanism. S S are two springs hanging from the yoke J and hooked under the ends of I, so that the whole apparatus hangs upon and is weighed by these springs. The yoke J passes through an eye in K, where it rests upon a knife edge, so as to equalize the tension of the springs; a

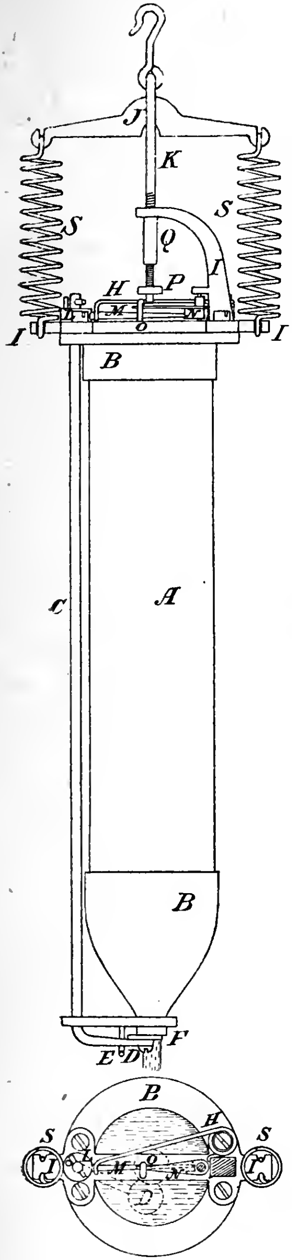


FIG. 10.

hook is also jointed to this eye, by which the apparatus is suspended from a fixed support. The remainder of the mechanism is for the purpose of automatically closing the valve when the flow of water has reduced the weight to a fixed, though adjustable, amount, and is as follows: Upon the top of *C* is a loose collar *L*, having a light arm *M* projecting from it; by means of the pin projecting from its upper surface it engages the pin passing through the top of *C*, and is thus able to close the valve *D* when forced in that direction by the spring *H*; it can, however, be drawn back again into the position shown without re-opening the valve. *N* is a detent revolving about a vertical axis, which receives the end of *M* and holds it in the position shown; the end of this detent being very thin it easily springs down and can be caught behind the hook *O*, against which it rests and thus maintains the parts in the position shown against the pressure of the spring *H*. Its pressure against *O* is, however, extremely small, owing to the reducing leverages of *M* and *N*, and being besides well oiled it requires but the slightest touch to free it, which is done by the adjustable screw *P*. On the lower end of *K*, which is produced below the eye for this purpose, is a nut *Q*, which is so set that when the vessel is nearly filled with water the curved arm of *I* (shown only in the elevation) settles down upon it; were it not for this device the opening of the jet *F* would start the vessel suddenly upward, throwing the springs into vibration; with the nut

properly set, however, the springs do not begin to act until the jet is completely formed, and most of the disturbance due to starting the jet and to starting the vessel upward, is thereby avoided.

When the vessel is filled, the orifice F is closed by means of a cork and the jet is started by loosening the cork and then pulling it out by means of a string fast to it, and pulled directly downwards.

The nut Q is made long enough to receive the screw P, which can be set so that as the vessel rises it will come against the detent N when the water is at any desired height in the vessel, thus disengaging M and closing D. Upon the closure of the valve the jet with its reaction disappears and the vessel becomes in consequence that much heavier; this difference in weight could be read off at once were the instrument constructed with a graduated scale or dial, as is an ordinary spring balance, but this would introduce the question of the accuracy of the springs and the indications on the dial could not be clearly seen from a distance, so that a better method has been devised. As soon as the valve closes the arm M and detent N are reset, and a beaker placed beneath the orifice F, the valve is then loosened just enough to let the water dribble out; as soon as enough has thus escaped to reduce the weight to the exact weight which the vessel had when the valve closed the detent is again automatically released and the valve tightly closed. There will now be in the beaker a quantity of water whose weight equals the reaction of the jet, and this is poured into a glass tube, whose section is double that of the jet, and placed besides the vessel for comparison. If the screw P happens to be set at a point unaffected by the small unavoidable oscillations of the springs, the correct value of the reaction will thus be shown, otherwise the mean of several experiments can be taken with P set in different positions. The height of the water at the first closure of the valve should be marked upon the vessel, and this will be the theoretical height for the water in the measuring tube, neglecting the small velocity of the water in the vessel, friction, etc., inasmuch, however, as the jet has always less than the theoretical velocity, the height after the second closure may be nearer to it. The apparatus, as thus arranged, gives a complete exhibition of the phenomenon without any calculations being needed.

Since the completion of this model I have at various times attempted to obtain an exact automatic register of the reaction throughout substantially the whole period required for the vessel to empty itself. The device last constructed succeeds admirably, and its main points will therefore be described.

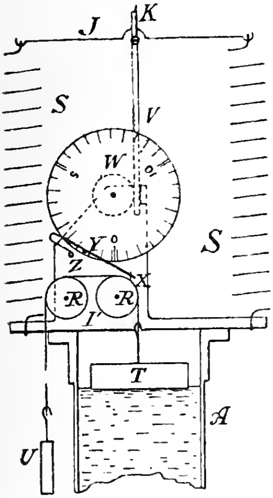


FIG. 11.

Fig. 11 shows a schematic view of the apparatus mounted upon the top of the vessel for registering the reaction. The piece *I* is replaced by another, *I'*, suitable for supporting the different parts of the mechanism, and having also places for the attachment of the springs *S S*; the piece *K* is also replaced by another having a place to attach the end of the rack *V*. This rack engages the toothed wheel *W* fast to the back of the graduated disc, so that this disc is made to revolve as the springs alter in length, and may therefore be regarded as the dial of the spring balance. The disc *W*, rollers *R R* and pen *X Y Z* are all mounted on the piece *I*, and move therefore with the vessel. The rollers support a band of thin tracing paper, eyeletted at the ends so as to connect easily with the float *T* and counterweight *U*, and as the water runs out nearly two feet of this band passes beneath the pen *X*. This pen is exceedingly light, being formed of straw and quill, with a fine wire spring hinge at *Z*, where it is attached to a pin adjustable in a hole in *I*. The pen itself at *X* is perhaps $\frac{1}{8}$ long by $\frac{1}{16}$ of an inch wide, and its handle is a piece split out of a straw about $1\frac{1}{4}$ inches long by $\frac{3}{32}$ of an inch wide. At *Y* a small ivory point is cemented to this straw handle, and the spring is so set as to press this point lightly sideways against *W*, while it also presses the pen *X*, charged with ink, gently down upon the paper band.

Instead of having a spring to close the valve, there is one to open it, either wholly or in part, as desired, and this is set free by burning a thread. The operation of the mechanism must now be evident. As the water flows out, a line is traced upon the band, and in this line slight indentations or notches are made by the graduations upon the revolving disc *W*, which are deep enough to

sufficiently admit the ivory point Y. After thus obtaining a register of the heights of the water and corresponding weights of the apparatus, the pen is lifted and the band turned over, and a second register made upon it in the same way, except that the valve is allowed to open just enough to let the water escape quickly in a horizontal sheet; there is then no vertical reaction, and the indentations serve to standardize the graduations on the dial by showing the height of water necessary to bring each line on W beneath the ivory point when the valve is closed. If, finally, a zero point be marked upon the band, such that with this point at X, the bottom of the float would be even with the orifice F, which must be done by measurement, we shall have on the two sides of the transparent band a series of distances from the zero point to the notches, and each distance will be the height at which water stood above F, that is, the "head" above F, at the time the notch was made. The distance to any particular notch on the second side of the band will, however, be a height of water which was exerting its whole weight upon the spring, and the distance to the same notch on the first side will indicate that greater height of water which showed the same weight on the dial, because only a part of its weight was felt by the springs, the remainder being sustained by the reaction of the jet. In order to distinguish the different lines on W from each other, and to make the notches show this distinction, some of the lines are triple and others double.

To get results free from the not-easily-avoidable oscillations of the springs, the distances on the first side are plotted horizontally upon cross-section paper as abscissas measured from a point F, representing, therefore, zero height, and so appropriately marked with the same letter as the orifice, and the corresponding distances on the second side are set off vertically as ordinates. If now a right line be drawn as nearly as possible through the points, it should, neglecting the consideration of friction and other refinements, pass through F and make an angle with the horizontal whose tangent is the cross-section of the vessel minus twice that of the jet and the difference divided by the cross-section of the vessel, or about sixteen-seventeenths for this model in which the jet is 0·32 and the vessel 1·86 inches in diameter. The value of the tangent is also seen to be $a \div p$ in *Fig. 12*, which shows a piece of the

paper band full size, five inches being cut out to bring the zero point F within the limits of the cut.

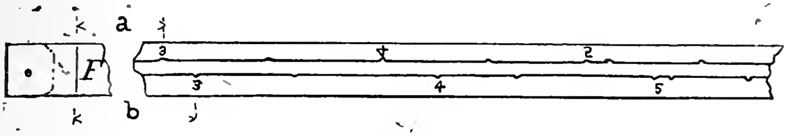


FIG. 12.

The results obtained from this apparatus are quite accurate and agree with those calculated by the formula.

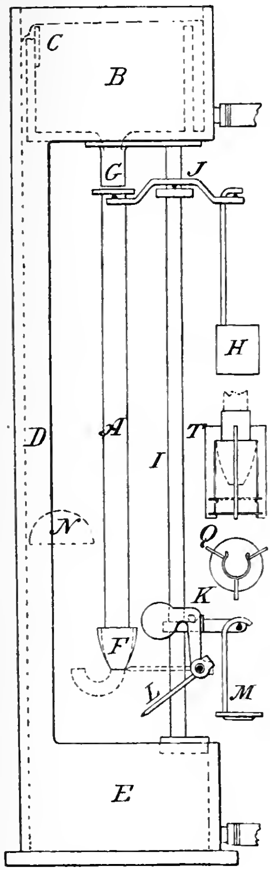


FIG. 13.

The reaction model, with continuous flow, is shown in *Fig. 13*. The vessel A has a bore of about half an inch diameter, while the opening at F has about half the area of the vessel, so that the velocity of exit is about double that of the flow through the vessel. The supply is maintained constant by a suitably constructed supply chamber, into which the water enters by the hose at the right, and has its velocity checked by a perforated diaphragm, so that the water in the chamber proper is comparatively at rest. C is an adjustable weir, by which the height of the water, or "head," can be regulated and maintained constant in spite of slight variations in the supply; the waste water escapes over the weir and runs down the inside of the back D into the waste box E, from whence it escapes by a hose. The head is regulated to maintain such a velocity in the supply pipe G, as will just keep the vessel A full, thus delivering to it a jet of suitable velocity and diameter at atmospheric pressure, as explained in a previous part of this article. If the water be delivered at G with too great a velocity, the vessel will not receive it all, and if with too little, some air will be drawn in, which will be perceived in the jet at F. Rotation of the water entering the

supply pipe, is prevented by suitable guides, not shown. *I* is a brass rod, or tube, which supports the scale beams *J* and *K*, on the former of which the vessel is hung, so as to be exactly under the orifice *G*. The jet piece *F* is detachable so that other jet pieces can be used, as indicated by the dotted piece for delivering a jet vertically upwards; other pieces, for horizontal and inclined jets, can be used, the centres of the jet orifices being all at the same height. *N* is a hood for catching the water from the vertical jet and delivering it down the back *D*. The jet pieces being also all of the same weight the "pee" *H* can be adjusted to balance exactly the empty vessel with jet piece attached. The bent lever scale beam *K* has a counter-balance formed on it, so that it exerts no horizontal pressure on the jet piece, except that due to the weights upon the scale pan *M*. With a downward jet it is not used, but is needed with all others, the thrust piece, also balanced, being raised into the dotted position shown and its knife edge entered into a notch in the jet piece exactly opposite the orifice. With the dotted upward-jet piece shown, its use is simply to maintain the vessel in a vertical position. *T* and *Q* are an elevation and plan of a deflector attachment, to be used with the downward jet for obtaining the reaction of the same independent of other forces.

This deflector attachment consists of a three-armed frame *T*, which slips onto the vessel just above the jet piece, the arms extending past the same and sustaining the deflector in either of two positions beneath it. The deflector is a thin disc of metal which rests in notches in the arms and receives the jet of water, spreading it into a thin sheet and allowing it to escape horizontally in all directions; a cylindrical shield is used to catch it and lead it to the waste box. If the upper scales are balanced with the water running and the deflector not in place, and again balanced after the latter has been inserted, the excess of the latter weight over the former will be equal to the downward reaction or impact of the jet striking the deflector plus the weight of the deflector, so that the reaction of the jet is thus obtained directly. Inasmuch, however, as the velocity of the jet is increased by falling through the distance from *F* to the deflector, there are two sets of notches, so that the deflector can be placed either one or two inches below *F*, and from the difference in weight caused by this change an allow-

ance can be made equivalent to placing the deflector exactly at F. With this allowance made the difference in weight equals the reaction of the jet issuing from F. The weight of the vessel when the water is running and the deflector frame removed is equal to the weight of the vessel full of water plus the reaction of the entering minus that of the issuing jet, plus the friction along the tube, but the weight of the vessel and water can be found by corking the orifice F and weighing it full of water, and the lower jet reaction has been determined as above, so that we get the upper jet reaction and friction from this weighing. It is intended to have a lower jet piece fitting without friction in the pipe, but supported from without, so that the friction of the stream against the pipe can be directly weighed; it has also been proposed to accomplish the same result by hanging a thin band of the same material as the tube from a balance above the supply box, so that this band shall occupy a diametral position along the whole height of the vessel, and thus receive the friction the same as the walls of the tube do. The velocity of the water in the jets must be found by catching it for a definite number of seconds and weighing it, which also furnishes a test of the uniformity of the flow. In the figure, no water is supposed to be in the apparatus, although its level in the supply chamber is indicated by a dotted line.

This apparatus works with great accuracy and a delicate balance can be obtained and maintained. The condition of atmospheric pressure at the point G is secured with great nicety by the device of the open space between the supply tube and vessel; to further establish this point an improvement is contemplated by which to test this pressure at any time with a water gauge. The experiments already made have been with the vertical jet only, and they agree well with calculated results.

THE MARTIN FIRE-PROOFING PROCESS.

BY PROF. ARTHUR BEARDSLEY.

[*Abstract of Paper read at the Stated Meeting of the* INSTITUTE, *September 21, 1887.*]

Many attempts have been made to discover a process for rendering tissues, wood, etc., uninflammable. The fearful losses of life and the great destruction of property by fire make the question one of the greatest importance. The object sought has been the discovery of a means of so protecting combustible materials that they will ignite with difficulty, burn without flame, and cease burning when the source of heat is removed. The objection to former processes has been that the fire-proof quality has not been permanent, causing the necessity of frequent and costly renewal.

The Martin process is cheap, easily applied, is not poisonous or corrosive, does not alter texture or color, and secures to fabrics a *durable* uninflammability. It has been subjected to the most severe tests by the eminent French chemists, Dumas, Paliard and Troost, acting as a Committee of the Society for the Advancement of National Industry, not only in the laboratory, but also in the theatres, the tests extending over several months and to a wide range of combustible materials, with the result that the process is now compulsory in all the theatres of France. Similar tests have been made in Turin, by Profs. Sobrero and Carlevaris, with the most satisfactory results.

In this country, the process has been most thoroughly investigated by Profs. J. Ogden Doremus and Henry A. Mott, who certify that it renders all combustible matter absolutely uninflammable; that it protects wood from decay and from the ravages of insects; that it is a most reliable and effectual fire extinguisher; that its effectiveness is *permanent*; that it is easily and generally applied, and is inexpensive; that it is neither poisonous nor corrosive, and affects neither textures nor colors.

The materials to be treated are dipped into a solution of the "glycero" and left there about fifteen minutes, after which they are allowed to dry, or are ironed dry if desired. As a paint, the "glycero" salts are mixed with the usual pigments and oil, and

applied with a brush in the usual way. Some of the specimens here shown have been treated for several months, one piece of wood having been "dipped" in 1885. Some of these materials are naturally of the most inflammable character, as light dress goods, newspapers, cotton wadding, excelsior, etc., but the "treated" specimens, as you see, defy our efforts to make them burn, simply charring under the intense heat of the Bunsen burner. Its cost is less than one-half cent per yard for the lighter fabrics. The "glycero" composition does not differ materially from other fire-proof compositions, except in the addition of a quantity of glycerine, to which its permanence is due. The composition is made up somewhat differently for different materials, one form of which, as contained in Dr. Mott's report, being as follows:

	Per Cent.
Glycerine, 28° B.,	9·71
Carbonate of ammonia,	4·85
Chloride of ammonium,	38·84
Cream of tartar,	3·84
Oxalate of potash,	3·84
Boracic acid,	38·84
	100·00

Prof. H. A. Mott, of New York, when called upon, alluded to the character of the tests conducted by the Committee to determine the duration of the process, which test consisted in exposing tissues, woods, fabrics of all kinds, which had been treated by the Martin process, to a temperature of 115° F., in an oven for over seven months, during which time currents of dry and moist air were alternately passed through the chamber, the articles thus exposed being as perfect after the test as before.

He then gave the composition of the Martin mixture, and stated that the success of the preparation was due to the presence of glycerine, which tended to hold the salts in solution (so to speak), thus protecting them from being evaporated or vaporized at ordinary temperatures, as it is well known that glycerine does not evaporate. The pressure of glycerine in the salts used for fire-proof paint, seems to prevent crystallization or disintegration of the salts, so that on the application of heat the paint film is more elastic, not cracking like ordinary paint films, thus exposing the untreated wood to the action of the flame, but causing the film to swell and

hold together as the gas generated by the decomposition of the salts form by the application of the flame. Dr. Mott stated that the value of the process consisted in being able to locate the flame or fire, so that it would be unable to spread the flame, simply charring the wood or fabrics at the point of application.

The GRAMOPHONE.

By. Prof. Edwin J. Houston.

The early promises of the actual practical applications of Mr. Edison's phonograph have never yet been fully realized, and this, too, despite the fact that much ingenious work has been expended on its improvement.

The causes of such failure are two-fold:

(1.) The phonograph, as originally constructed, failed to correctly reproduce articulate speech.

It gave readily, with fair accuracy, the pitch of the uttered sounds, and, to a certain extent, reproduced their intensity or loudness; but it failed, almost completely, to give anything but approximations of the loudness or intensity of the overtones on which the quality of the speaker's voice depends. That is, although the spoken words were readily recognized, the speaker's voice could not readily be distinguished, especially when the words spoken into the phonograph were uttered in a loud tone.

(2.) The phonograph-record, as originally obtained, was of a perishable nature, and failed to reproduce the spoken words more than a comparatively few times.

The record was received on a sheet of tin foil, so that when the stylus or point attached to the diaphragm, when used to reproduce the speech, was caused to traverse the record a few times it gradually wore off the ridges, or changed the configuration of the hollows, thus either entirely obliterating the records, or rendering them unintelligible. When used to receive the speech, this diaphragm may be called the transmitting diaphragm; when used to reproduce speech, it may be called the receiving diaphragm.

The difficulties already alluded to arose to a great extent from the fact that in the original form of phonograph the movements of

the diaphragm, under the influence of the sound waves, caused the point attached to said diaphragm to indent the sheet of tin foil, on which the point rested, to depths, the extent of which varied with the amplitude of the vibrations of the diaphragm. The distance between indentations of the same order represented the wave lengths, or, in other words, the record was traced or engraved on the tin foil, as alternate hollows and ridges of varying depths, as must of course have been the case, since the cutting or indenting stylus or point was moved at right angles to the surface of the tin foil.

The extent to which the indentations of the phonogram-record accurately copied the movements of the transmitting diaphragm, necessarily measured the accuracy with which such record could reproduce exactly similar movements in the receiving diaphragm and thus reproduce exact copies of the original sounds. To what extent is this similarity maintained?

Evidently no difficulty exists to correctly impress on the record the frequency of the to and fro movements of the transmitting diaphragm so far as the fundamental tones of the spoken words are concerned, nor, indeed, to a great extent, the relative frequency of the overtones. But, a very serious difficulty arises when it is endeavored to preserve in the record the amplitude of the motion of the transmitting diaphragm, especially the relative amplitudes of the additional or over-tones. The cause of this difficulty is to be found in the fact that the degree of resistance to indentation, offered by the tin foil, or indeed by any ordinary material, does not increase in the same ratio as the depth of indentation, but in a much more rapid ratio. It therefore follows that the relative depths of the phonogram-record indentations are not a correct reproduction of the movements of the transmitting diaphragm, consequently the phonogram-record is unable to correctly reproduce the quality of a speaker's voice, on which a recognition of the same depends.

Under these circumstances, it is evident that there will be a closer reproduction of the quality of any tone, when the same is uttered into the receiving diaphragm in a low tone, since then the differences in the intensities of the over-tones are less pronounced. This fact was noticed, in the early use of the phonograph, but the construction of the apparatus was such as to necessitate the use of

very loud tones, when it was desired to cause the reproduced tones to be heard by many people at once.

It should be borne in mind, therefore, that perhaps the principal cause of the failure of the early form of the phonograph to come into extensive commercial use, did not arise from imperfect or incomplete mechanical construction, or, indeed, from the character of the material employed for the phonogram-record, but from a faulty underlying principle, viz., *from the fact that the recording stylus was moved at right angles to the surface that received its cuttings or indentations.*

The difficulties just pointed out, it would seem, must exist in any instrument, however improved in its mechanical structure, if it makes the record on the phonogram-record at right angles to the surface thereof. Of course, if a substance was discovered for such a surface, that offered a resistance to indentation exactly proportional to the depth of such indentation, the difficulty would, to a great extent, be removed.

It would not, however, be entirely removed. It is essential to the correct reproduction of the movements of the transmitting diaphragm, that the stylus should move over the record-surface without perceptible friction, or at least without any change in the amount of the friction. Unless this is possible the record will, as before, not only be weakened, but modified. It is therefore difficult to see how any form of phonographic or, perhaps more correctly, phonautographic apparatus, in which the stylus moves at right angles to the surface of the recording sheet, can correctly reproduce articulate speech.

The objection to the indenting stylus thus moving at right angles to the surface of the recording sheet is not, however, limited to the failure of the phonogram-record to be correctly impressed with the movements of the transmitting diaphragm. A record so made, as a rule, is incapable of correctly impressing all its recorded peculiarities on the receiving diaphragm; and thus, again, the characteristic movements of the transmitting diaphragm are still further departed from, or, the sounds received, differ still further from the sounds transmitted.

The cause is evident. The receiving diaphragm, as is well known, is caused to move to and fro and thus produce the sounds, by means of a suitably attached stylus, the point of which is caused

mechanically to move over the phonogram-record. As it passes over the indentations, the diaphragm moves in or out, according to whether it is moving up an elevation, or down a depression.

Such motion, however, is positive in but one direction; viz., while the stylus is climbing an elevation or ridge, motion in the opposite direction being produced by the elasticity of a spring or of the diaphragm itself. If, in order to copy all the peculiarities of the record, the tension of the spring, or the pressure of the stylus on the record surface be increased, rapid wear ensues. If, on the contrary, to avoid this, the stylus be rested too lightly on the record, it will often, on the outward movement of the diaphragm, entirely leave the surface, and thus, either greatly mar the clearness of the reproduced sounds, or render them quite unintelligible.

We understand that Mr. Edison has been at work, for some time past, in improving the phonograph as originally created by him, and that he claims to have greatly improved the instrument, and that he will soon place the same on the market.

Meanwhile, however, Mr. Emil Berliner, of Washington, D. C., known to the scientific world from his labors in connection with the telephone, has invented an improved form of phonograph, in which the difficulties heretofore existing in such instruments have been very nearly, if not entirely, removed. Indeed, if what is claimed for the new instrument be true, which from a strictly scientific standpoint certainly appears to be extremely probable, the art of the stenographic reporter bids fair, at least to a considerable extent, to become one of the lost arts.

Mr. Berliner calls his instrument a gramophone, and, under this name, has patented it in the United States, under Letters Patent No. 372,786, dated November 8, 1887.

The following description of some of the forms of apparatus, as well as most of the figures, are taken from the United States Letters Patent before alluded to.

Before entering into a detailed description of Mr. Berliner's apparatus, it may be mentioned that the respects wherein the same differs from the earlier forms of phonograph are mainly two-fold; viz.:

(1.) In the fact that the record is traced on the phonogram sheet in a direction parallel to the surface of such sheet, instead of at right angles thereto as heretofore.

(2.) That in place of a material like tin foil, which is objectionable on account of the resistance it offers to the free movements of the tracing point attached to the diaphragm, there is employed a surface that offers but little resistance to such movements.

These improvements are of a radical character, and will, it is believed, do much to render possible the commercial use of the instrument.

Mr. Berliner's description of the objects of his invention is so tersely put, that we will quote certain parts thereof.

"By the ordinary method of recording spoken words or other sounds for reproduction, it is attempted to cause a stylus attached to a vibrating diaphragm to indent a travelling sheet of tin foil or other like substance to a depth varying in accordance with the amplitudes of the sound-waves to be recorded. This attempt is necessarily more or less ineffective, for the reason that the force of a diaphragm vibrating under the impact of sound-waves is very weak, and, that in the act of overcoming the resistance of the tin foil or other material, the vibrations of the diaphragm are not only weakened but are also modified. Thus, while the record contains as many undulations as the sounds which produce it, and in the same order of succession, the character of the recorded undulations is more or less different from those of the sounds uttered against the diaphragm.

"There is then a true record of the pitch, but a distorted record of the quality of the sounds obtained. The simple statement that the material upon which the record is made resists the movement of the diaphragm is not sufficient to explain the distortion of the character of the undulation, for if that resistance were uniform, or even proportional to the displacement of the stylus, the record would be simply weakened, but not distorted; but it is a fact that the resistance of any material to indentation increases faster than the depth of indentation, so that a vibration of greater amplitude of the stylus meets with a disproportionately greater resistance than a vibration of smaller amplitude."

The difficulties here pointed out are removed by the inventor by the happy idea of moving the recording stylus parallel with the recording surface, as is done in the well-known phonautograph of Leon Scott. This change in the direction of motion permits a ready change in the character of the recording surface.

The structure of the apparatus will be better understood from inspection of *Fig. 1*. In this form of instrument the recording sur-

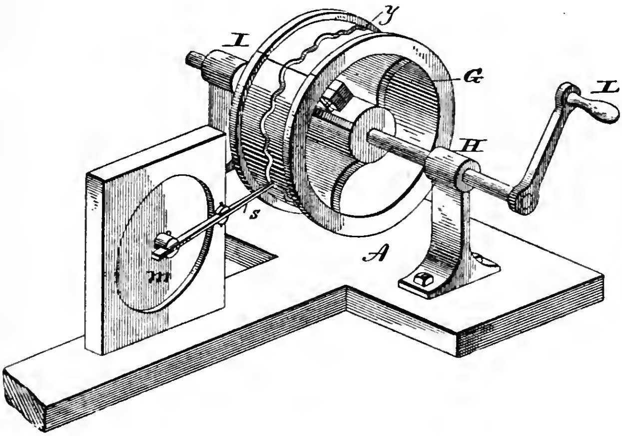


FIG. 1.

face is the surface of the cylinder or drum *G*, mounted on a shaft or axis supported by the standards *H*, *I*, so as to be readily rotated by the winch *L*. The drum *G*, may, as shown in the figure, be provided with flanges *e e'*, *e e'*, *Fig. 2*, *e'* projecting beyond the general

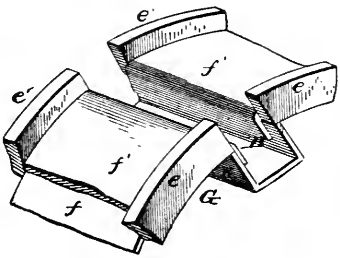


FIG. 2.

surface *f*, of the cylinder. From the edges of a gap *B*, left on the cylinder surface, the side walls of a box *K*, extend as shown.

A layer *f'*, *f'*, of thin felt, or other yielding elastic material, is wrapped on the cylinder surface, and bent over the edges of the gap and serves as the support of the record surface, both while recording and reproducing.

The recording surface is secured at both ends to bars *c*, and *d*, as seen in *Fig. 3*, and is then placed on the supporting surface, the

bars c, and d, being placed in the gap B, before alluded to. The record sheet is tightly stretched on the surface of the drum, by

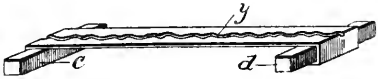


FIG. 3.

means of bolts passing through the bars c, and d, and its two ends brought into true alignment in the same plane.

The record sheet employed by Mr. Berliner in this form of apparatus consists of a sheet of paper, or parchment, or of a thin strip of flexible metal, placed as described on the surface of the drum, and subsequently covered with a layer of soot or lamp-black by slowly turning the drum while exposed to a smoky flame. The advantages of such a surface are thus set forth by the inventor:

"It is well known that a layer of lamp-black thus deposited, while it adheres well to the surface of a solid body, is nevertheless easily removed from the same. It requires only an exceedingly small force to draw a plainly-visible line upon such surface, owing to the fact that the spicules of carbon of which lamp-black is composed are only loosely superimposed upon each other, and are exceedingly light. All this has long since been recognized and utilized in the production of phonautographic records, and I take advantage of these facts in my improved method of recording and reproducing sounds."

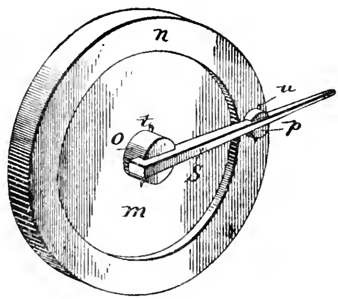


FIG. 4.

The diaphragm m, shown more clearly in *Fig. 4*, is rigidly mounted in a frame, n, so that its plane is at right angles to the axis of the drum G.

A post O, attached to the centre of the diaphragm, is furnished with a slot in which is received a stylus S, pivoted at t. This stylus, which projects over and beyond the frame, has its free end just in contact with the record-surface, and is also pivoted by a pin u, in a slot provided in a post p, on the frame n. The stylus p, therefore acts as a lever with its fulcrum at u, and the movements it receives from the diaphragm m, are limited to deviations practically parallel to the record-surface.

If then, while sounds are directed against the diaphragm, the drum is rotated with uniform speed by means of the crank L, the movements of the diaphragm cause the free end of the stylus to vibrate to the right and left of its position of rest, and thus traces on the lamp-blacked surface a sinuous or undulating line y, *Fig. 5*.

Fig. 5.

A record, therefore, is thus obtained of the sounds uttered against or in the neighborhood of the diaphragm.

It is evident from the nature of the recording surface, and the direction of movement of the recording stylus, that

(1.) That a line of uniform depth is traced in an easily yielding surface;

(2.) The slight friction thus experienced by the recording stylus is independent of the amplitude of the vibrations;

(3.) The vibrations of the diaphragm, therefore, are not modified or changed as in the case of the instruments heretofore in use.

The record having thus been obtained, is then flowed with any quick drying varnish which preserves the lamp-blacked surface. There now remains the process whereby it is copied in solid resisting material. The author mentions three processes; viz.:

(1.) A copy in metal by the purely mechanical process of engraving.

(2.) A copy by chemical deposition.

(3.) A copy by photo-engraving. The latter process is preferred by the inventor.

To the above might be added the process of electro-metallurgic deposition.

The process of photo-engraving is, however, the simplest, and permits not only the most accurate copy to any indefinite extent in copper or nickel, without destroying or injuring the record. A

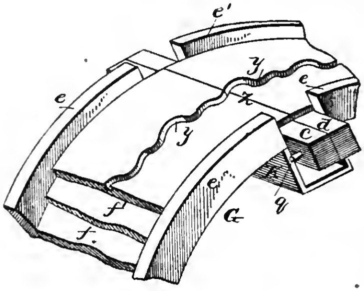


FIG. 6.

record thus reproduced is shown, in *Fig. 6*, attached to the surface of the drum *G*. A section of the same is shown in perspective in *Fig. 7*.

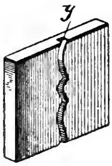


FIG. 7.

The copied or reproduced record is now placed on the drum *G*, as shown in *Fig. 6*, care being taken to obtain an exact meeting of the two ends of the sinuous or undulatory groove. The drum is now rotated, with the same speed as that it had on receiving the record. The end of the stylus is thus forced to follow the sinuous grooves *y*, and the diaphragm *m*, *is vibrated positively in both directions*, and in strict accordance with the undulatory groove. It must therefore reproduce the sounds uttered into the diaphragm correctly as to pitch and quality.

As regards the intensity of the reproduced sounds, it is evident, as the inventor has stated, that since the phonautographic record may readily be enlarged, the intensity or loudness of the reproduced sounds can be increased to almost any desired extent.

That Mr. Berliner's gramophone, or an apparatus constructed in substantial accordance with the novel features thereof, will come

into extended commercial use seems to be rendered probable by the following considerations; viz.:

(1.) It effects such an accurate reproduction of spoken words as to render it possible to preserve the characteristic speech of distinguished people or of friends or relatives.

(2.) The record it produces is imperishable, and will reproduce the original sounds as often as may be desired.

(3.) The record may be indefinitely reproduced, being comparable in this respect with the printed record of a book.

Since the resistance to the movements of the inducting stylus is reduced to nearly a minimum by the use of Mr. Berliner's apparatus, it is evident that the speech may be recorded even when the speaker is talking in an ordinary tone.

Mr. Berliner's claims in the U. S. Patent before referred to are quite broad, as will be seen:

(1.) The method or process of recording and reproducing spoken words and other sounds, which consists in first drawing an undulatory line of even depth in a travelling layer of non-resisting material by and in accordance with sound vibrations, then producing the record thus obtained in solid resisting material, and finally imparting vibrations to a sonorous body by and in accordance with the resisting record, substantially as described.

(2.) The method or process of reproducing sounds recorded phonautographically, which consists in copying the phonautographic record in solid resisting material, and then imparting vibrations to a sonorous body by and in accordance with the copy of the original record, substantially as described.

(3.) The method or process of reproducing sounds recorded phonautographically, which consists in copying the phonautographic record in solid resisting material by the process of photoengraving, and then imparting positive to-and-fro movements to a sonorous body by and in accordance with the copy of the original record, substantially as described.

A more recent form of gramophone will be seen in *Fig. 8*, the cut for which, and for *Fig. 9*, were kindly furnished by the *Electrical World* of New York.

In this form of apparatus the mechanical details only are altered. The receiving surface is a disc of smooth glass rotated at a uniform rate by the descent of a box loaded with shot. The uniformity of

speed is secured by means of the fan shown at the left of the figure. The recording surface is the lower surface of the glass disc. The stylus and diaphragm are placed as shown, and are connected to a tube furnished with a peculiarly constructed mouth-piece to ensure ease of talking.

FIG. 8.

The glass disc, before being coated with the lamp-black, is covered with a uniform layer of printers' ink by passing an ordinary printers' roll over its surface. Thus prepared it appears to take a more adherent deposit of lamp-black.

In this form of apparatus suitable arrangements are made to give the disc a progressive movement so that the stylus traces the

sinuous, or undulating line in a spiral, such for example as that shown in *Fig. 9*, where a section only is represented.

Whether or not the gramophone will realize in actual practice the numerous practical applications it seems to offer, remains of course to be seen. It has in its favor the advantages already pointed out. It has as a drawback, which may prove to

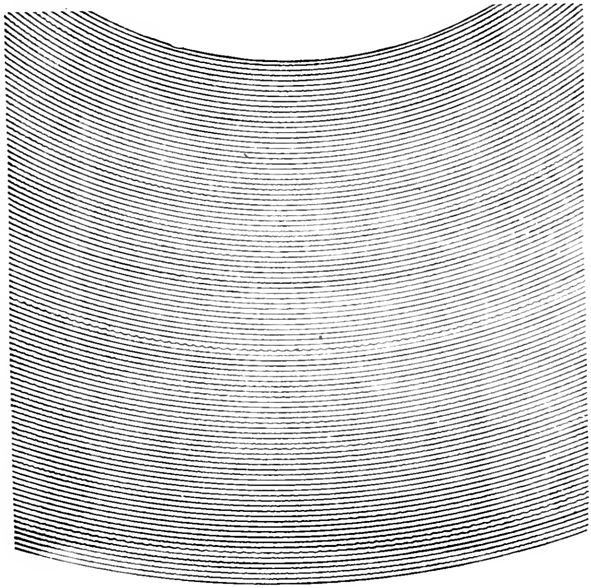


Fig. 9.

be more or less serious, the necessity that exists for the reproduction of the record in hard metal, which involves processes that require long practice and manipulative skill. These, however, are mechanical difficulties, and will, we believe, readily be overcome.

Central High School.

Philadelphia, November 2[illegible], 188[illegible].

ELECTRICAL MEASUREMENTS, ESPECIALLY AS APPLIED TO COMMERCIAL WORK.

By Prof. WM. A. ANTHONY.

[*Abstract of a Lecture delivered at the* FRANKLIN INSTITUTE, *November 25, 1887.*]

The lecturer was introduced by Prof. Edwin J. Houston, as follows:

Ladies and Gentlemen: We are fortunate this evening in having with us one well known in electrical circles in this country. Indeed, so well and favorably has he been known as a practical electrician, that he has been induced to leave a position which he has for so many years held with distinguished success. I take pleasure in introducing to you Prof. Wm. A. Anthony, formerly in charge of the Department of Electrical Engineering in Cornell University, and now consulting electrician of the Mather Electrical Company.

PROFESSOR ANTHONY:

Mr. President, Members of the INSTITUTE, and Ladies and Gentlemen—The subject I have chosen for this evening's lecture is one of the driest that could well have been chosen, but I have believed it to be of sufficient importance to warrant its presentation to an audience such as I suppose would be attracted to the FRANKLIN INSTITUTE meetings. Thousands of men and millions of capital are to-day interested in the applications of electrical science. We have come to a point where hap-hazard work is no longer admissible, where electrical currents must be gauged and measured, where the electrical properties of materials must be accurately determined, where, in short, machines and apparatus must be built to a gauge, and their products measured electrically as well as mechanically. As in mechanical construction we have gone beyond the use of the foot-rule and carpenter's square, and are fixing our dimensions by standard gauges to the ten-thousandth of an inch, so in the electrical construction we have gone beyond measurements by rude and imperfect instruments, and have got to a point where, if our machines and apparatus are to find their place in the markets of the world, we must gauge our work by accurate electrical standards.

What are the electrical quantities we have to measure? Before attempting to answer this question, let us consider for a moment the origin of the terms we shall have to use. Our electrical nomenclature has been derived from the fluid theory of electricity. We talk about an electrical current as though something were flowing; we talk about quantity of electricity as though we considered it something to be weighed or measured; we talk about capacity for electricity as though a body could be filled with and hold a certain quantity of it, as a vessel may be filled with water. Whence comes the idea of an electric flow?

If we go back to the early electrical experiments where insulated bodies were "charged" and then discharged—the electricity drawn off, as it were—by a wire connecting the insulated body to the earth, we see that the idea of something accumulated in the body and then conveyed away by the wire was a very natural one, and when we found that the wire was heated, the passage of *something* through it seemed to be proved. Then came the voltaic battery and the evidence of greater and greater effects as the cells in series were increased, a close analogy to increasing pressure causing a more rapid flow of fluid. It was seen that many cells in series gave power of overcoming obstacles, that insulation had to be more perfect to prevent escape. Hence the terms high tension and low tension, as these were applied to gases.

There is some misapprehension among those who have had only a practical acquaintance with electrical phenomena and do not know the fundamental principles. I hear a great deal of talk about high tension currents and low tension currents, as though the currents themselves were different. It should be understood that a current of one ampère is always a current of one ampère, always conveys one coulomb per second whether the tension be high or low, just as a stream that conveys one gallon of water per second, is the same stream whether under high or low pressure. The term tension is a misnomer as applied both to electricity and to gases. Pressure is the proper term for gases and may be used by analogy for electricity. Potential is the scientific term for the electrical condition for which the word tension has been used. We can best understand it by drawing the analogy between it and fluid pressure. We find in the evening that the gas is burning dimly. We say at once, too little pressure in the mains.

If more pressure is put on, more gas is forced through the burners and our lights burn more brightly. If our incandescent lights burn dimly, it is a lack of potential. Let the potential in the wires be increased, more electricity is forced through the carbon filament with an improvement in the light. It is not the greater pressure that gives you the brighter gas light, but the larger quantity of gas that the greater pressure supplies. So it is not the increased potential that causes the increased brightness of the carbon filament, but the greater flow resulting from the higher potential.

The electrical quantities we wish to measure are then *quantity*, which is measured in units called *coulombs*, and may be considered as analogous to pounds of a gas or liquid:—*potential*, measured in *volts*, analogous to pounds per square inch of fluid pressure:—*capacity*, measured in *farads*, analogous to cubic feet of a vessel for holding fluids:—and *strength of current*, measured in *ampères*, for which there is no close analogue in fluid measurements. Yet in electrical measurements, strength of current is, perhaps, most important of all, and furnishes the fundamental unit of the system. Another quantity of great importance in electrical measurements is the *resistance* of bodies to the flow of electricity. It is measured in *ohms* and may be compared, qualitatively, to the frictional resistance which fluids experience in flowing through pipes.

Let us consider now these several quantities and their relations to each other, from the standpoint of the analogy of a flowing fluid. Here is a pipe carrying gas. We wish to know how much gas is flowing through it per hour or day or month. This the gas meter professes to tell us, but there is sometimes a question whether its statements are truthful. We could run the gas into a suitable vessel and measure it, but that would be inconvenient in the practical use of the gas because we consume it as it flows. But whatever method we use, our object is to determine the total quantity of gas delivered in a given time, and not the rate of flow at any instant. By *rate of flow* I do not mean the velocity of the gas, but the rate as indicated by the quantity of gas flowing in unit time when the flow is uniform. In this sense, when the same quantity of gas per minute is flowing, the rate of flow is the same whatever the size of the pipe. But there is no important effect of the gas dependent upon the rate of flow; the pipe that conveys it acquires no new properties or

powers. In fact, no effect is produced by it that would indicate to us whether the gas were flowing or not. To be sure, heat is generated by the friction of the gas, but in practice this is too small to be perceived and is of no consequence. Moreover, the heat generated is a function of the velocity of the gas and not simply of the rate of flow as I have used that term. We have, therefore, no need to know the rate of flow of a gas, we make no attempt to measure it directly, we have no unit in which to express it, and no distinctive name for it as a quantity.

Now let us compare an electric flow. Here is a wire conveying an electric current. We know there is something going on it because we see the effects on beyond, just as we know that gas is flowing in this pipe because we see it burning in yonder burner. As with the gas, we can determine the quantity of electricity flowing in a given time by measuring its effects. Electricity flowing through acidulated water generates hydrogen and oxygen gases. The quantity of these gases generated in a given time may be taken as a measure of the total amount of electricity flowing. Electricity flowing through a solution of a metallic salt, as copper sulphate or silver nitrate, deposits the metal. The weight of deposited metal will measure the total flow. But these methods, like the methods of measuring gas, tell us only the average rate of flow and not the rate at any given time. But, a conductor conveying electricity, unlike a conductor conveying fluid, exerts forces due to the current in it. This wire will deflect a magnetic needle, will attract iron filings. (Shown by experiment.) In short, it develops all around it a magnetic field.

This effect of an electric flow is of such great importance and finds such a multitude of applications, that the rate of flow upon which it depends is a more important element than the total quantity flowing, and the unit in which we measure it, the ampère, is based upon this magnetic effect. This unit has taken its place with our foot, and pound, and gallon, and is making its way very rapidly into the popular vocabulary. Notwithstanding the fact that it is coming into such general use, there seems to be a great deal of confusion as to what an ampère is. It seems to me important that the true definition of this unit current should not be lost sight of, and I wish to protest against the admission of the

arbitrary definitions that are finding their way into electrical literature.

The true ampère is based upon the absolute unit current as defined by the British Association committee. The absolute unit current is that current, a centimeter length of which will produce a unit magnetic field at a centimeter distance, or it is that current which when flowing in a conductor bent into a circle of one centimeter radius, will develop at its centre a magnetic field of intensity 2π. This is the foundation of the electro-magnetic system of electrical measurements. Upon this unit are based all the other units of the system. The *ampère is one-tenth of this unit.* This was the value of the weber, the former name of the unit of current, and the Paris congress, in changing the name to the ampère, did not change its value, but expressly voted that this should continue to be its signification.

Now to measure an electric flow in ampères. We may bend the conductor into a circle and compare the field produced at the centre of the circle with some known magnetic field, such as the magnetic field due to the earth. This is accomplished by means of the tangent galvanometer. The conductor, of one or many circular convolutions, is placed with its plane in the magnetic meridian; in this position the force it produces is at right angles to the earth's magnetic force and a little needle placed at the centre of the circle will take a position depending on the ratio of the two magnetic fields. If the needle stand at 45° with the magnetic meridian, the two fields are equal, and, in general, the ratio of the field produced by the current to that of the earth, is the tangent of the angle that the little needle makes with the meridian.

In the great tangent galvanometer of the Cornell University, this method is employed to measure currents up to 300 amperes. The great difficulty in this method is that the earth's magnetic field is not constant but varies from day to day and from hour to hour. In all work where accuracy is aimed at, the horizontal intensity of the earth's magnetic field must be determined at the time of making an observation for current. In the Cornell instrument a coil suspended by a wire serves to determine the horizontal intensity by balancing the force developed by a current in the coil in the earth's field against the force of torsion of the suspending wire. But another and more serious difficulty is met with when any

attempt is made to use this method for ordinary practical work. The earth's magnetic field is greatly affected by the presence of magnetic substances. A small mass of iron is sufficient to change very greatly the value of the earth's field in its vicinity. A large magnet or a dynamo may at many feet distance change the earth's field by a hundred per cent. The tangent galvanometer can only be used, therefore, where there are no disturbing causes. It cannot be used in a dynamo station or in a workshop. But in a suitable place, it is invaluable as a standard with which to compare other instruments. The Cornell tangent galvanometer is mounted in a special building, constructed entirely without iron and placed at a distance from all other buildings. The earth's field there is subject only to such changes as are due to natural causes, and with the appliances for determining these changes the highest class of work can be done.

We need, however, instruments for measuring currents in the workshop and about dynamo machines, and a great variety of instruments called ammeters have been constructed for these purposes. In general, such instruments consist of a coil of wire developing a magnetic field which is compared with an artificial field produced for the purpose, or the magnetic force developed by the coil in the presence of some other magnetic field is balanced by some known force. To be more explicit, one form of ammeter consists of a coil which tends to deflect a needle against the artificial field of a permanent magnet. The accuracy of these instruments depends upon the constancy of this opposing field. But no permanent magnet does remain constant, and these instruments, therefore, need to be frequently calibrated. Another form of ammeter is one in which the coil acts upon a mass of soft iron, developing a force which is opposed by a spiral spring. Here the accuracy of the instrument depends upon the constancy of the spring and upon the constancy of the effect of the little mass of iron.

And here let me say that a magnetic field is not of itself a force. To have *force* there must be two magnetic bodies, and the force exerted depends as much upon the one as upon the other. A coil of wire conveying a current develops a magnetic field, but before a force can be produced something else that can also develop a magnetic field, as a mass of iron, a magnet, or

another coil of wire carrying a current, must be brought within the range of its action. If this second body can only produce a weak field, then only a feeble force will be produced. Moreover, the force will vary with every change in this second body, even if the current in the primary coil remain constant.

Speaking of this fact, of the necessity of two magnetic bodies to develop a magnetic force, reminds me of a question often asked in regard to extracting particles of steel that have become imbedded in the eye. Would not a sufficiently powerful magnet draw it out? I always tell the questioner that the most powerful magnet in the world could exert but a small force upon a little particle of steel. If you can loosen the piece of steel, a magnet is a very good means of taking it out of the eye, but then a small magnet does as well as a large one. I was once told by a gentleman that he had known of a sewing needle that was deep down in the flesh of the leg being drawn out by the application of a powerful magnet. I remembered how little force the most powerful magnet can exert where a sewing needle is the body attracted, and thought to myself that the statement needed confirmation. Some of you will remember that when it was proposed to build the 1,000 feet iron tower in Paris, it was predicted that all the loose iron articles, knives, joiners' tools, chains, tin pans, to say nothing of wagon tires and horse shoes, would come rushing pell-mell to the base, in consequence of the tower becoming a great magnet by the earth's induction. Yet, notwithstanding the prediction, I do not think I should take the precaution to leave my keys and pocket knife this side the water if I were going to visit Paris after the erection of the great tower

But to return to our ammeter, the little mass of iron is attracted by the coil, because it becomes itself a magnet. If it become a strong magnet, it is attracted strongly; if it become a weak magnet, it is attracted feebly. Its magnetic strength will not be the same under all circumstances, and the force exerted by the coil upon it is, therefore, not always the same when the same current is flowing. I have recently re-calibrated an Ayrton and Perry instrument of the permanent magnet type, and found its constant had changed sixteen per cent. since last March. Last spring I calibrated two spring ammeters at the same time, and found one to read five per cent. fast, while the other was nearly as much slow

Do not understand from this that I consider these instruments of little value: They are the best we have. What I want to impress upon you is the importance of frequent comparison of the instruments with others known to be standards. Theoretically, the best ammeter is one in which the force exerted between two coils in the same circuit is opposed by gravity. Here the force developed depends only upon the current which it is desired to measure, and the opposing force is the one force at our command that does not have to be watched and tested, but is the same to-day as yesterday, and can be trusted to be the same to-morrow as to-day. Such an instrument would, therefore, give uniform indications. (Thomson instruments exhibited.) There are, however, practical difficulties in the way of constructing such an instrument for the measurement of large currents. One of the coils must be movable, and it is difficult to take a large current to and from it without imposing some constraint upon its motion. We still want for commercial use a really good ammeter for measuring large currents, one that we can trust as we trust our scales for weighing merchandise, to give correct indications for weeks and months and years.

I have dwelt thus upon these instruments, which measure rate of flow, because, as I have already said, some of the most important effects of electric currents depend upon this element There are cases, however, where we wish to know the total quantity of electricity flowing in a given interval, and care nothing for the rate of flow at any given instant during that interval. For instance, we are furnishing a house with incandescent lights. It is important to know the quantity of electricity furnished per month. The unit in which we measure electricity in such cases is the quantity conveyed in one second by a current of one ampère. This is the coulomb already spoken of. It has not been found easy to construct a reliable coulomb-meter. The Edison Company use a meter in which the current deposits zinc upon a zinc plate. This is a very good method for the laboratory, but it is difficult in practice to fulfil all the requirements for completely reliable meters. At least, so far as I can learn, neither the consumers nor the company seem to be perfectly satisfied. The new coulomb-meter exhibited and described by Prof. Forbes about a month ago, at a meeting of the Electrical

Engineers in New York (and in this Hall) depends for its action upon the development of heat in a wire by the flow of the current. The wire, in the form of a flat spiral, is placed below a little windmill. The flow of electricity in the wire heats it, and so sets up air currents that cause the little windmill to revolve. A train of wheel-work, connected with the windmill, actuates the hands in front of a dial. Thus the instrument registers the flow of electricity as a gas meter registers the flow of gas. Practical experience only can tell whether this instrument will fulfil all the requirements.

But the measurement of currents or of quantities of electricity is but a small part of what is required in electrical measurements. Potential in many cases is quite as important an element as strength of current or quantity. To go back to our analogy of a flowing fluid, we know that pressure is necessary to bring our gas to the burners, but so long as it is sufficient to supply gas in proper quantity and gives us a good light, we do not trouble ourselves about it. It is the business of the gas company to maintain the required pressure, and they must adjust by a pressure gauge. It is the chemical energy of the gas that gives the light, and the energy due to the pressure is too small an item to be considered. But suppose we are supplying steam or compressed air for driving engines, the pressure is now a more important item. The power used is the product of pressure by volume of steam used per second. Pressure is, therefore, one of the items that the consumer pays for. Where electricity is supplied for any purpose, the energy which the consumer pays for is the product of potential by quantity. Varying either factor varies the energy delivered, and measurement of potential is, therefore, as important as measuring quantity or current. The unit in which we measure potential is based upon the relation just stated, that the product of potential by quantity gives the electric energy. The absolute unit potential is the potential under which the absolute unit current performs the absolute unit work in unit time. A true volt is 100,000,000 absolute units.

Before taking up the methods of measuring potential, let us consider the other electrical units and their relations to those already defined. The farad, the unit of capacity, is the capacity of a body which contains one coulomb when charged to a potential of one volt.

At a potential of two volts, the same body would contain two coulombs, but its capacity is still one farad. It is as though we were to define a gallon as the capacity of a vessel which holds one pound of air under a pressure of one atmosphere. Under two atmospheres the same vessel would hold two pounds, under half an atmosphere half a pound.

The ohm is the resistance of a conductor in which the volt maintains the current of one ampère. These are the true definitions of these units and need to be carefully considered when our measurements involve the determination of electric energy. To see how this is important let us consider the actual measurement of a resistance. To measure a resistance upon the basis of the definition just given is a very difficult operation. So difficult that even after twenty-five years of such measurements we do not feel very certain of the value of the ohm. In 1862, the British Association appointed a committee to determine the ohm and construct standards. After some years of labor, standards were produced, consisting of coils of wire supposed to have the resistance defined as the ohm. From these, resistance boxes are constructed and resistances are measured by comparing the unknown with these known resistances. This is a very simple matter and can be quickly and accurately done. The difficulty of measuring a resistance upon the basis of the definition of the ohm, is shown by the fact that later determinations indicate that the British Association standard, now known as the B. A. ohm, is about one and three-eighth per cent. too small. The Paris Congress, recognizing the difficulty of arriving at a positive value on account of the discrepancies between the results of different observers, adopted a standard, the resistance of 106 centimetres of mercury one millimetre in cross section, to be called the *legal ohm.* This, according to the best of our present knowledge, is about one-quarter of one per cent. too small. They further decided that the unit current should retain the value assigned by the British Association, and adopted as the *legal volt* the potential difference that maintains a current of one ampere in the legal ohm. The legal volt is, therefore, about one quarter of one per cent. too small.

Now suppose we have measured a current in ampères and the potential in legal volts; multiplying, we obtain the energy,

but, since the unit in which potential is measured is too small, the result is too large and must be reduced one-quarter of one per cent. to obtain the true energy. I think it unfortunate that the legal standard was not made 106·25 centimetres of mercury, for it seems certain that this amount, to the fourth figure at least, is the correct value of the ohm. If the legal ohm had been so chosen, computations of energy based on measurements in legal units would not have been in error by more than one-tenth of one per cent., and for all ordinary purposes corrections would have been unnecessary. The measurement of a potential in legal volts is not a difficult matter. It consists in measuring the current maintained in a conductor whose resistance is known in legal ohms. A standard instrument for such a purpose would be a delicate galvanometer whose coils consisted of many turns of wire of a known high resistance—of high resistance, because the instrument must take so little current from one point to the other as not appreciably to alter the difference of potential between them. (Experimental illustrations.) A multitude of volt-meters for commercial measurements are on the market, most of them being instruments similar to the ammeters already spoken of, but with coils of very fine wire in which a current, proportional to the difference of potential, is produced. In fact, the ammeters and volt-meters often look so much alike that they could not be distinguished, except for the words "volts" and "ampères" on the dial. These instruments are as likely to change as the corresponding ammeters and require the same precautions as regards calibration.

But there are other ways of measuring potential that do not depend on the measurement of a current. If two plates are connected, one to one point and the other to another, the difference of potential between which is wanted, these two plates, when brought near together, attract each other with a force proportional to the potential difference. This force of attraction is, however, very small and requires an extremely delicate instrument to indicate it, until the potential difference is 400 or 500 volts. (Thomson's voltmeter shown.) Another method of measuring potential is to balance the unknown against a known potential. The difficulty in applying this in practice is to obtain a reliable standard. Voltaic cells afford the best means of obtaining a fairly constant potential difference, but only under very exact conditions are these potentials

sufficiently uniform to be accepted as standards. (Potentials of cells measured.) A gravity cell that had been in use some time gave a deflection of 46. One set up about eight hours before the lecture gave 64, and one set up just at the beginning of the lecture gave 65.

A form of instrument known as the Wirt volt-meter, as furnished by the Electrical Supply Company, of Chicago, uses the Daniels cell, of special construction, as a standard. The cell consists of three square bottles cemented together side by side. In one of the outside bottles is the zinc in zinc sulphate, communicating with the middle bottle by a small hole near the top. The other outside bottle contains the copper in copper sulphate and communicates with the intermediate bottle by a hole near the bottom. In the middle bottle is a valve which when closed prevents communication between its upper and lower parts, and so prevents the mixing of the two liquids. This valve is to be opened only at the time of making an observation. No doubt such a cell made up from pure materials would give the same potential for a considerable time.

I have so far avoided the use of the term electro-motive for I find there is a good deal of confusion as to the exact use of it even among physicists. I find it stated in some works of high authority that electro-motive force and difference of potential are synonymous terms, and again that difference of potential produces electro-motive force. I have seen it stated in a very excellent text-book on electricity by one of our foremost electricians, that the electro-motive force of a voltaic cell is the result of the difference of potential between the poles.

I can best illustrate what I conceive to be the difference between the two terms by referring again to the analogy between the electric flow and the flow of fluids. Gas is flowing through this pipe. Take two points, A and B, and suppose the flow to be from A toward B. A pressure gauge would show a higher pressure at A than at B. Water flows in your water mains. A pressure gauge will show a higher pressure at any point than at any other point further on in the direction of the flow (it is supposed that the points considered are at the same level). The difference of pressure is the cause of the fluid flow. It is the force that moves

the fluid, the *fluid-motive force.* Electricity is flowing along this wire.

I have shown that there is a difference of potential between the different points along the wire, and we accept that difference of potential as the cause of the electric flow between the two points. If we know nothing of the pipe except between the two points considered, we cannot assign any other cause for the flow of the fluid through it except the difference of pressure, but we know the difference of pressure must have a cause, and if we are at all inquisitive we shall not be satisfied with saying the difference of pressure is the fluid-motive force, but we shall trace the pipe back and try to discover the cause of the difference of pressure. Tracing the pipe back we find, by and by, a stand-pipe in which the water level is far above any of the outlets from which water is drawn. This accounts for the pressure of the water in the pipes, but still we are not satisfied. There must be a cause for the high level in the stand-pipe. Investigating further, we find a system of pumps which forces the water into the stand-pipe, taking the water, perhaps, from the same level to which our pipes discharge it. Here we find a water-moving force that is not water pressure, without which the pressure that moves the water in our pipes would soon cease, and the flow stop.

Suppose now that all our outlets are stopped and that no water flows from the stand-pipe. What results? The pumps go on working, the water in the stand-pipe rises higher and higher, and if the pipe is high enough and strong enough, the water will rise till the force of the pumps is balanced, and they will stop. The pressure now exerted by the water column measures the water-moving force of the pumps. We can tell by it just what is the force we have at command for moving water. This force is the water-motive force of our system. It must be sufficient to overcome the resistance of our pipes and carry the water to the highest levels we wish to reach when the flow is most rapid. Open a cock, the water flows and lowers the level in the stand-pipe, the back pressure upon the pumps is diminished, they begin to work, and maintain the water at nearly its former level. Open another cock, the level falls a little more and the pumps work faster. Make more and more openings, and the water in the stand-pipe falls more and more till, by and by, the level in the pipe is but little above that of the supply

from which you pump. Water is being used at such a rate that the force of the pumps is little more than sufficient to drive the water through their own passages. It is not the water-motive force that has failed, but the carrying capacity of the pumps.

Now note the analogy in the case of the voltaic cell. We have found on this wire a difference of potential from point to point. Trace the wire back and we find an apparatus whose office it is to maintain the potential difference. What is its action? By some means, which we do not understand as well as we understand the action of a water pump, this apparatus takes electricity from one of the plates, N, in the liquid and forces into the other, P. In the second plate, P, the electricity is at a higher level, and so flows through the wire to the plate N to be forced back to P through the liquid. Cut the wire and almost at once the electricity in P reaches the highest pressure, level, or potential, that the cell can produce. All action in the cell ceases, and the difference of potential between it and P now measures the force the cell can exert to move electricity, the *electro-motive force* of the cell. This electro-motive force is something that depends upon the materials of which the cell is made, and is absolutely independent of its size. The smallest cell, one made of a copper musket cap holding a drop of water, and a bit of zinc of the size of the point of a pin, as I have often shown experimentally, has the same electro-motive force as a cell of the same materials of the largest size; just as the water motive force of a small pump, its power to produce pressure, may be just as great as that of a larger one. Let us follow the analogy. I connect P with N by a small wire. This is like opening a single stop-cock on our water service. The electric level is lowered, but the cell begins to work and maintains the potential at very near its highest value, another wire allows more electricity to flow, still more lowering the potential, and it is possible to open so free a path for the passage of the current that the cell can no longer maintain a considerable potential difference, and the limit of the capacity of the cell to supply electricity is reached.

Note that the limit here is not due to any falling off of electro-motive force, but to the fact that nearly the whole electro-motive force is required to carry so much electricity across the liquid from plate to plate. Here exactly is the advantage of a large cell over a small one—a large cell, like a large pump, can maintain a high

pressure, even when there is a large draft upon it. I think you will now see the distinction between the terms difference of potential and electro-motive force. Difference of potential is *one* electro-motive force. But the general term, electro-motive force, includes all causes of the movement of electricity. There may be a flow of electricity without a difference of potential, but there can never be a flow without an electro-motive force.

I could give you examples of a great variety of electro-motive forces, but one more will suffice.

I move this rod across the earth's magnetic field. I know that an electro-motive force is developed, causing a flow toward the end at my left hand. That end, I am sure, is for the moment at a higher potential. When I stop, the electricity flows back and equalizes the potential. Connect the two ends by a wire leading to a sensitive galvanometer, and the flow of current is demonstrated. This movement of a wire across any magnetic field develops a difference of potential between the two ends, and if the wire form a closed circuit, a current will flow. I said just now that we could have a flow without difference of potential. Here is a case. A magnet thrust end-on into the centre of a wire hoop produces an electro-motive force, which acts equally all around the hoop, causing a flow, but without difference of potential. Here, too, we may find an analogy in the flow of liquids. Suppose a trough in the form of a ring to contain fluid, and let an endless rope be laid in it and made to move around the trough. (Illustrated on black-board.) The liquid will be dragged along by the rope, but there is no difference of pressure or level anywhere.

Following out this analogy to fluid motions is very useful in leading to clear views of very many other electrical phenomena, for, although nothing is really explained, an unfamiliar fact seems to us more plausible when we find in it a close analogy to a fact with which we have been long familiar, and about which we have no question. Take the case of the operation of electric motors. We know that an electric motor develops an opposing electro-motive force, and every electrician knows that this opposing electro-motive force is the secret of the operation of the motor, that mechanical power cannot be developed without it, but I find that few people except those familiar with the theory, are willing to believe that this counter electro-motive force

is of any use. I have known of some motors being constructed with the avowed object of reducing the counter electro-motive force as much as possible, with the idea that it was a hurtful resistance, preventing the motor from developing its full power. But how is it with a fluid flowing through a pipe? In order to make it do work we must construct a machine to produce a counter pressure. A water motor always checks the flow of water.

Take the simple case of a rotary motor. (Rotary motor on blackboard.) Let it run at full speed and suppose there is no friction. It offers no resistance to the flow of the water. The water flows with the same velocity as though the motor were not there and it does no useful work. Begin now to load the motor, you check its speed and at the same time check the flow of water. As you increase the load you check the flow more and more. The force exerted upon the motor will be greatest when it is brought to rest, and the flow in the pipe stopped; then the water will exert its greatest pressure, but since the motor does not move, it can do no work. Between these two conditions of no power to do work, when moving with the full velocity of the water but without force, and when receiving the full pressure of the water without moving, there must be a condition of maximum power, or maximum rate of working, and we can readily admit that this occurs when the back pressure of the motor is half the *water-moving force.* At this speed half the *water-moving force* is effective in running the motor and half goes to waste in the velocity with which the water leaves the motor. The efficiency of the motor is, therefore, only fifty per cent. It would be far better, if so much power is needed, to use a larger motor and run it at slower speed and at less than its maximum power, and let less of the energy of the water to go to waste.

Now, note the analogy between this and the electric motor. When the electric motor is running it develops a counter electro-motive force which corresponds to the back pressure of the water motor. When this counter electro-motive force equals half the electro-motive force of the generator, the electric motor is giving its maximum power; but it is using only half the energy of the electric current, the other half going to waste in developing heat in the conducting wires leading to the motor, and in the motor itself. Just as with the water motor, it is better to use a larger size

electric motor and let it run at such a rate that it will develop a counter electro-motive force equal to more than half the electro-motive force of the generator, and while developing less than its maximum power perform a work equal to a larger percentage of the energy given to it. The difference between the water motor, which I have taken for an example, and the electric motor, is this, that while the water motor exerts the greatest back pressure when it is stopped, the electric motor exerts the greatest counter electro-motive force when it is running at the highest speed. Otherwise, the analogy between the working of the two is very close, and the efficiency of either one of them is exactly the ratio of the back pressure which it exerts to the possible pressure which can be brought to bear upon it.

In bringing this lecture to a close I wish to acknowledge my own obligation to Mr. Ives, who has kindly loaned and operated his lantern for projecting the views on the screen; to J. W. Queen & Co., for the loan of nearly all the apparatus used and exhibited here this evening, and to Mr. C. H. Richardson and Mr. Metzgar of the firm of Richardson & Metzgar, who have given their services for the whole day, with the resources of their workshop, for the preparation of the apparatus for the experiments. Without their assistance the preparation of the experimental illustrations would have been impossible. Thanking you for your kind attention, I now close.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

TWO CRYSTALLIZABLE BODIES, PTEROCARPIN AND HOMÓPTEROCARPIN EXTRACTED FROM SANDERS.—R. Cazeneuve and L. Hugouneng, *Ann. Scien. Indust. de Lyon* (through *Jour. Soc. Dyers and Colourists*, **3**, 9).

The first researches upon the chemical composition of sanders wood are due to L. Meier, who isolated from it a red crystallizable body, which he called santalin. He extracted the santalin by exhausting the wood with ether; the extract was washed with water and dissolved in alcohol, and then precipitated with acetate of lead, the liquid being afterwards freed from lead by means of sulphuretted hydrogen or sulphuric acid, and the santalin separated out.

Weyerman and Haeffely, as the results of analyses, gave the formula $C_{15}H_{14}O_5$ to the body prepared according to L. Meier's directions.

Weidel treated the wood with a boiling alkaline solution, and then filtered and neutralized the liquid; from the precipitate formed, which was dried, he separated, by means of ether, a colorless crystalline body, which he called santal, and to which he gave the formula $C_8H_6O_3 + \frac{1}{2}H_2O$.

On treating with alkalies santal forms protocatechuic acid and carbonic acid like piperonal, with which it is isomeric.

On completely exhausting sanders wood, Weidel separated from the last extracts an irregularly crystalline body, colorless, like the santalin of L. Meier. Weidel gave this new body the formula $C_{14}H_{12}O_6$.

Later than 1878, Franchimont and Sicherer separated from sanders and caliatur wood an amorphous body, melting at 104°, and having the composition $C_{17}H_{16}O_6$. When this body is treated in a closed vessel with hydrochloric acid, about one molecule of methyl chloride is formed from one molecule of the body.

A black resin remains, from which an amorphous body $C_8H_{10}O_5$ can be extracted; from the acid solution left, a body crystallizes out in needles, but has not been further examined.

Three years previous to the publication of the last research, in 1875, one of the authors, by exhausting with ether an intimate mixture of powdered sanders wood and slaked lime, had obtained a well crystallized body having the formula $C_{12}H_{10}O_3$. This body, differing from the bodies previously mentioned, was shown on further examination to be a mixture.

The powdered sanders wood is intimately mixed with its own weight of freshly-slaked lime. It is moistened with water and dried on a water bath, and then exhausted with ether.

The lime forms an insoluble lake with the coloring matter, and with the resins it forms resinates which are not very soluble. On distilling to dryness, the ether passes over yellow in color, and the residue is redissolved in the smallest possible amount of alcohol of B. P. 93°. On cooling, two bodies—pterocarpin and homopterocarpin—crystallize together, mixed also

with resinous matter; a second crystallization leaves them almost pure; on crystallizing from boiling ether, the mixture of the two bodies separated. The laminated crystals of homopterocarpin are easily distinguished from the long needles of pterocarpin. The two bodies are separated by means of pure carbon bisulphide, which easily dissolves homopterocarpin in the cold, and leaves the pterocarpin almost untouched, as it is only soluble in a large excess of the boiling solvent.

The sanders wood contains almost five grammes of homopterocarpin and one gramme of pterocarpin per kilogramme.

PTEROCARPIN.

This body is white, well crystallized, insoluble in water, insoluble in cold alcohol, more soluble in boiling alcohol, and not very soluble in ether, from the boiling solution of which it separates in laminated crystals. Bisulphide of carbon does not dissolve it in the cold, but dissolves it better boiling. It separates from chloroform in fine prisms.

Pterocarpin turns the plane of polarized light strongly to the left.

On the following percentages an analysis showed it to possess the empirical formula $C_{10}H_8O_3$. It is neutral in its reactions, insoluble in acid, insoluble in concentrated potash, even at the boil; it is acted on by melted potash, and gives an odor resembling cumarine; nitric acid dissolves it with a green color.

HOMOPTEROCARPIN.

It forms a white, well-crystallized substance, soluble in ether, chloroform, bisulphide of carbon and benzene. Alcohol dissolves it very little in the cold, but easily at the boil, and it separates on cooling in splendid needles several centimetres in length.

Like pterocarpin it turns the plane of polarized light to the left.

Homopterocarpin corresponds to the formula $C_{12}H_{12}O_3$, there being a difference of 2 CH_2 from pterocarpin.

Concentrated potash (forty per cent.) does not affect homopterocarpin, even on heating to 200° for four hours in a closed vessel.

Melted potash affects it at 240°, white fumes being given off, and an odor of cumarine, when it is dropped on the potash in small portions. The body is thus decomposed, forming carbonic acid, and a phenol giving the color reactions of phloro-glucin, which is extracted with ether after neutralizing the potash with sulphuric acid.

On heating five grammes of homopterocarpin with ten grammes of concentrated hydrochloric acid in a sealed tube to 120°, a black metallic-looking resin is obtained, like that obtained by Barth and Weidel on heating resorcin with concentrated hydrochloric acid in sealed tubes to 190°. These chemists obtained in this way resorcin ether $OH \cdot C_6H_4 — O — C_6H_4 \cdot OH$. The body thus obtained is separated in the same manner as that obtained from homopterocarpin. The acid remaining in the tube is colored yellow. If the acid is evaporated and the residue taken up with ammonia, a fluorescent coloring matter is obtained, having the appearance of fluorescein. Methyl chloride

can be detected in the tube by the green color of its flame and the formation of methyl sulphide.

These reactions seem to show that homopterocarpin is a polyatomic phenol containing methyl groups. From its stability in presence of alkalies, it appears to be an aromatic anhydride of the cumarine series.

Pterocarpin probably belongs to the same group. H. T.

DETERMINATION OF POTASSA IN ASH, MINERALS, MANURES, ETC.—In order to avoid repeated and troublesome evaporations, Kretschmar (*Chemiker Ztg.*, **87**, 418), recommends the following simplification of Stohmann's method whenever potassa alone is to be determined:

Five times the quantity of material required for a potassa determination is dissolved by means of hydrochloric acid, if possible, the iron oxidized by a few drops of nitric acid, and the sulphuric acid precipitated by barium chloride, and the solution then super-saturated hot with ammonia and carbonate of ammonia.

The mixture (solution and precipitate) is then evaporated to dryness in a porcelain dish at least at a temperature of 110° C. After adding a few drops of ammonia, the residue is extracted with hot water. The solution is made to measure 500 c. c., and 50–100 c. c. are taken for the determination of potassa. If little magnesia is present, the solution is evaporated immediately in a platinum dish, and, after expelling ammonia salts, treated with solution of platinic chloride. The presence of a large quantity of magnesia requires a prolonged washing of the platinic double chlorides, because of the difficult solubility of the magnesium platinic chloride. In this case, it is preferable to previously evaporate the measured quantity of the filtrate with an excess of oxalic acid, and after gentle igniting, re-extracting and filtering, the solution is then precipitated with platinic chloride.

This method is applicable in presence of the acids of sulphur, silicic, phosphoric, boric, hydrofluoric acids, iron, aluminium and chromium, the alkaline earths and magnesia and small quantities of manganese. O. L.

COLLOIDAL CUPRIC SULPHIDE. W. Spring and G. de Boeck (*Bul. Soc. Chim.*, **48**, 165).—Among the probable causes of the solubility or insolubility of substances in any liquid, the degree of condensation or polymerization is one of the most important, and the insoluble substances may be regarded as polymerides of others, capable of existing in simpler forms. The number of mineral substances presenting a soluble and an insoluble modification is as yet quite limited, the hydroxides of iron and aluminium, and the sulphides of arsenic and antimony being the best known. A solution of cupric sulphide may be prepared by precipitating any cupric solution by hydrogen sulphide and washing the precipitate with an aqueous solution of hydrogen sulphide. As the foreign matters are removed, the cupric sulphide gradually dissolves, yielding a liquid that is black when examined in mass, but brown when viewed in thin layers, and having a feeble greenish fluorescence. The best results are obtained by the precipitation of an ammoniacal copper salt.

When the solution is boiled, the hydrogen sulphide may be completely expelled without notable precipitation of cupric sulphide, and the analysis of

the liquid then shows that the proportions of copper and sulphur are exactly those required for the formula CuS. Such solutions keep well if the proportion of cupric sulphide is not greater than five grammes to the litre of water; stronger solutions cannot be kept longer than a few hours. Spectral analysis shows that the liquid is a solution, and does not contain suspended particles. W. H. G.

SIMPLE, EFFECTIVE, INEXPENSIVE AND SAFE ARTIFICIAL LIGHT FOR INSTANTANEOUS PHOTOGRAPHY.—Dr. Piffard, of New York, seems to have succeeded in producing a really practicable artificial illumination for photographic purposes. It is characterized by intense actinism, extreme simplicity in production, perfect controllability, freedom from danger, and inexpensiveness, as well as absence of some of the most objectionable features of artificial lights for this purpose. The basis is magnesium in fine powder, which is deflagrated with some suitable mixture, producing a highly actinic flash. More than twenty years ago, instantaneous effects were produced in this way by J. T. Taylor, on collodion plates, and, more recently, Gaedicke and Mieth, of Germany, have patented a mixture of the kind, which leaves nothing to be desired as to effectiveness, but which, like the other, is not adapted to very general use, because of a liability to spontaneous ignition and the unpleasant and injurious character of some of the products of combustion. Dr. Piffard found that a mixture of ordinary gunpowder (one part) with magnesium powder (three parts) ignited in an open space, gave a light of the desired quality, and that even the flash of a pistol loaded with the mixture answered for the production of negatives on gelatine plates. He finds it preferable, in most cases, to sprinkle the magnesium powder on a tuft of ordinary gun-cotton, on a metallic plate, and ignite it with a match; ten to fifteen grains of magnesium powder upon seven or eight grains of gun-cotton being sufficient for a single portrait. As might be expected, portraits by light from so large a surface are characterized by a softness unobtainable by other artificial illuminants. C. F. H.

BROMIDE ENLARGEMENTS FOR PREPARING SKETCHES FOR PHOTO-ENGRAVING.—It is proposed by F. C. Beach to use enlargements on bromide paper direct from the negative to assist the artist in preparing sketches in black ink, of any desired size, for photo-engraving in place of the ordinary chloride prints which must generally be first employed for making a negative of suitable size. The latter have been employed because they are readily bleached, so as to leave the black ink lines on a white ground, by bichloride of mercury. Mr. Beach has found that prints on bromide paper, fixed or unfixed, can be effectually and easily bleached out in about five minutes by immersion in the following solution, the bleaching action being assisted by movement of the solution. The alcohol in the formula is added to prevent the ink from spreading. Solution of bromide of copper is first prepared by mixing a solution of bromide of potassium 120 grains in four ounces of water, with a solution of sulphate of copper, 120 grains in four ounces of water, and the bleaching solution by using:

Bromide of copper solution	½ oz.
Hyposulphite of soda,	100 grains.
Alcohol,	1 oz.
Water,	2 oz.

C. F. H.

				H_2SO_4 turns violet. *Crocëin-Scarlet*.—7B. H_2SO_4 turns blue. *Ponceau*.—R, 4R. and G. H_2SO_4 turns eosin-red. *Coccin*. H_2SO_4 turns fuchsine-red. *Roccelin*. H_2SO_4 turns violet. *Bordeaux*.—G. and R. H_2SO_4 turns blue.

Artificial Dyestuffs Insoluble in Water.

Soluble in 5 per cent. caustic soda solution.	Insoluble in 5 per cent. caustic soda solution.
The alkaline solution is filtered, reduced with	Soluble in 70 per cent. alcohol.

The analytical tables for the qualitative examination of the artificial dye colors of commerce, recently published by Weingartner, have been enlarged and re-stated by G. Zetti (*Ber. (Austen. G., 1887–8)*) as follows:

I.—*Artificial Dyestuffs Soluble in Water.*

The aqueous solution gives a precipitate with the tannin reagent (25 tannin, 25 acetate of soda, and 250 water).

A.—Basic Dyestuffs.

The aqueous solution is reduced with zinc dust and hydrochloric acid, neutralized, put upon filter paper and gently warmed, when—

The original color reappears					The original color does not reappear.
Red.	Yellow or Orange.	Green	Blue	Violet.	
Fuchsine H_2SO_4 dissolves with yellowish brown color. *Neutral Red* H_2SO_4 dissolves with brownish green color *Safranine* H_2SO_4 dissolves with green color	*Phosphine* With alkalies in aqueous solution, yellow precipitate, which dissolves in ether with yellow color, fluorescing strongly green *Flavaniline* Similar precipitate, with alkalies, soluble, however, in ether without color but with blue fluorescence	*Malachite Green* Ammonia produces a rose-red or gray precipitate, H_2SO_4 colors it yellow on dilution *Brilliant Green.* Ammonia produces no, or very little, precipitate H_2SO_4 colors it yellow, on dilution slowly becoming green *Methyl Green* Ammonia decolorizes it, without a trace of precipitate. H_2SO_4 colors it yellow	*Methylene Blue* Caustic soda precipitates it violet black, H_2SO_4 colors it grass green *New Blue, B and D* Caustic soda precipitates it brownish-black *Bleu Nouveau.* Hot solution, violet, cold solution, green, caustic soda precipitates it brownish red *Muscarin* Tannin gives an indigo blue precipitate, caustic soda precipitates it reddish-brown.	*Methyl Violet.* (Hofmann's Violet.) H_2SO_4 yellow color, on dilution green, passing into blue violet *Neutral Violet* H_2SO_4 produces dirty violet color, on dilution, blue *Mauveine* (Rosolan.) H_2SO_4 produces gray color, on dilution, sky blue, passing into red-dish-violet *Amethyst* (Fuchsia Giroflee.) H_2SO_4 produces green color, on dilution, blue *Crystal Violet* H_2SO_4 produces orange color, unchanged on dilution	*Auramine.* Yellow, alkalies precipitate it white and milky, hot H_2SO_4 decolorizes it slowly *Chrysoidine.* Orange on wool, H_2SO_4 dissolves it with yellowish brown color. *Vesuvine.* Brownish-orange on wool, H_2SO_4 produces Havanna brown color *Victoria Blue.* H_2SO_4 colors it reddish-brown and then greenish-blue.

The aqueous solution does not yield a precipitate with the tannin reagent.

B.—Acid Dyestuffs.

The aqueous solution is reduced with zinc dust and hydrochloric acid.

The solution is decolorized; it is then neutralized, put upon filter paper and gently warmed, when—

The original color reappears. The aqueous solution is acidified with HCl and treated with ether.		The original color does not reappear. The dyestuff is heated on platinum foil.			The color of the solution does not disappear, but changes into a brownish-red shade. The color of the ammoniacal solution appears when put on paper.
The ether is colored	The ether is not colored	Deflagrates without colored fumes	The dyestuffs burn slowly, reddish-brown fumes forming or deflagrates easily, with formation of reddish-brown fumes. A dye-test upon unmordanted cotton fibre is—		
			Fast to soaping	Not fast to soaping.	
Phthaleins. *Eosine.* Yellow with H_2SO_4. On heating HBr. vapors given off, HCl precipitates the aqueous solution orange. *Safrosine* (Scarlet) Golden yellow, with H_2SO_4. On heating HBr. vapors given off; HCl precipitates brown. *Phloxine.* Golden yellow, with H_2SO_4. HBr vapors on heating. HCl precipitates flesh-colored *Rose Bengale* No fluorescence. With H_2SO_4 orange color, Iodine given off on heating. *Uranine-Chrysoline.* Solution is brownish yellow. HCl decolorizes it with formation of a brown precipitate *Coralline-Aurin* Solution eosine red. HCl gives a yellow precipitate. On heating, neither Br or I. given off	Sulphonated Rosaniline derivatives. *Acid Magenta* Aqueous solution, bluish-red. H_2SO_4 solution yellow, on dilution, red. *Helvetia Green* (Acid Green.) Aqueous solution, light green, alkalies decolorize it. *Alkali Blue*—B—6 B. Alkalies decolorize it. *China Blue* Aqueous solution, blue, alkalies do not change it *Acid Violet* Aqueous solution, violet, ammonia decolorizes it, H_2SO_4 colors it orange, on dilution becoming greenish-blue violet ——— *Induline-Nigrosine.* Aqueous solution, violet, gray. HCl precipitates it bluish, ammonia, reddish-violet	Nitro phenols. *Picric Acid* Aqueous solution, greenish-yellow, alkalies change it to dark-yellow; HCl produces no precipitate, deflagrates only mixed with soda. *Martius' Yellow.* HCl produces yellowish-white precipitate, soluble in ether. *Naphthol Yellow.*—S HCl produces no precipitate, insoluble in ether. ——— *Aurantia* Aqueous solution concentrated red, dilute yellow, alkalies in excess precipitate it dark-red	Benzidine-Azo Colors. *Congo Red.* Aqueous solution, red, blue, with HCl *Benzo-purpurine.* Aqueous solution, orange, HCl and concentrated H_2SO_4 precipitate brown. *Azo Blue.* Aqueous solution, blue-violet, alkalies produce blood-red solution ——— *Erythrosine.* Aqueous solution, bluish-red: on heating iodine sublimes	Azo Dyestuffs. *True Yellow*—R and G. H_2SO_4 turns yellow. *Diphenylamine Yellow.* (Tropæolin oo.) H_2SO_4 turns violet. *Azo Flavine* H_2SO_4 turns red. *Methyl and Ethyl Orange.* H_2SO_4 turns yellow *Yellow N Poirrier.* H_2SO_4 turns blue-green. *Luteoline* H_2SO_4 turns yellowish-green *Tropæolin o.* H_2SO_4 turns brown-orange *Mandarin.* H_2SO_4 turns carmine-red. *Biebrich Scarlet.* H_2SO_4 turns green *Crocëin Scarlet* H_2SO_4 turns indigo-blue. *Xylidine Ponceau.* H_2SO_4 turns violet *Crocëin-Scarlet*—7B. H_2SO_4 turns blue. *Ponceau*—R, 4R and G. H_2SO_4 turns eosin-red. *Coccin.* H_2SO_4 turns fuchsine-red. *Roccelin* H_2SO_4 turns violet *Bordeaux*—G and R. H_2SO_4 turns blue.	Anthracene derivatives. *Alizarine.*—S. Aqueous solution, brownish-yellow, ammoniacal solution, fuchsine-red. *Cœrulein.*—S. Aqueous solution, brown-olive, ammoniacal solution, green. *Alizarine Blue*—S. Aqueous solution, brown-red, ammoniacal solution, greenish blue.

Artificial Dyestuffs Insoluble in Water.

Soluble in 5 per cent. caustic soda solution. The alkaline solution is filtered, reduced with zinc dust and heat, and put upon filter-paper. The color of the alkaline solution—		Insoluble in 5 per cent. caustic soda solution.				
		Soluble in 70 per cent. alcohol.				Insoluble
		The alcoholic solution does not fluoresce		The alcoholic solution does fluoresce		
Reappears.	Does not reappear.	Becomes reddish-brown with 33 per cent. soda solution	No change with 33 per cent. soda solution.	Fluorescence disappears with 33 per cent. soda solution.	Fluorescence does not disappear with 33 per cent. soda solution.	
Gallocyanine Soda solution, violet. H_2SO_4 solution, blue *Galleine.* H_2SO_4 solution, indigo-blue *Cœruleine* Soda solution, green, H_2SO_4 solution, green *Gall[illegible]* Soda solution, yellow. H_2SO_4 [illegible]	*Canarine.* Soda solution, yellow insoluble in H_2SO_4 *Alizarine.* Soda solution, blue-violet, heated with zinc dust becomes red *Anthra and Flavo-purpurine* Soda solution, fuchsine-red *C[illegible]* Soda [illegible] H[illegible] *Nitro-Alizarine* Soda solution, red, reduced with zinc dust and put on filter-paper, indigo blue spots *Alizarine Brown.* Soda solution, [illegible] olive. H_2SO_4 [illegible] tion, [illegible] *Alizarine Blue* Difficultly soluble in soda, with green color, on filter-paper dirty-violet spots	*Induline-Nigrosine* Alcoholic solution, bluish green, extracted with benzene, deep reddish-brown fluorescence *Rosaniline or Diphenylamine-blue.* Alcoholic solution deep blue, with HCl greenish, no fluorescence with benzene	*Indophenol.* Alcoholic solution becomes reddish, brown with HCl	*Magdala-red* Alcoholic solution is bluish-red, with cinnabar fluorescence	*Primrose* Alcoholic solution is bluish-red, with yellow fluorescence *Cyanosine.* Alcoholic solution is bluish red, with brick-red fluorescence	*Indigo.* Powdered and reduced with zinc dust and NH_3 gives yellow solution, which, put on filter-paper, yields bluish spots

S. P. S.

A Simplified Platinotype Process, just published by Captain Pizzighelli, by which prints are produced directly in the printing frame without subsequent development, has rendered that process one of the simplest printing processes, and may do much to bring it into competition with the silver process, especially as it seems to afford either a glossy or matt surface. This is accomplished by adding to the sensitizing solution some vehicular substance, in practice gum-arabic or arrow-root, which prevents the penetration of the paper by the solution, and at the same time some one of the usual developing agents, as ammonium or sodium ferric oxalate, together with the chloro-platinite of potassium. Reduction of the platinum salt thus takes place in the printing frame, and, as the picture becomes visible, the exposure can be judged as accurately as in the silver process, whilst all the subsequent operations of the silver process of washings, toning, fixing, etc., are replaced by simple washing, first in acidulated water and then in ordinary water for ten or fifteen minutes; which completes the process. The sheet rubber or waxed paper, to prevent effect of moisture, is also unnecessary. Several modifications in working are practicable. The prints may be under-exposed and laid aside in the dark for several hours, to be brought up by a continuating action which takes place, or they may be still more under-exposed and be developed as usual.

Time is wanting to permit definite statement as to the keeping qualities of the paper, but samples have remained unchanged for several weeks.

C. F. H.

The Identity of Inosite and Dambose. Maquenne (*Bul. Soc. Chim.*, **48**, 162).—In 1868, Aimé Girard discovered among the products of the action of hydriodic acid on the dambonite, obtained from crude Gaboon caoutchouc, a saccharine substance having the composition $C^6 H^{12} O^6$, to which he gave the name dambose. The properties of this substance closely resembling those of inosite, of which the preparation from walnut leaves and the constitution had been studied by the author (this Journal, cxxiii, 498), the relations of the two compounds suggested a closer investigation. The dambose was prepared by Girard's method (*Comptes Rendus*, **67**, 820), and in its properties and those of its acetyl derivatives was found to be identical with inosite; the latter substance, therefore, seems to be widely disseminated in vegetable organisms. Dambonite is dimethyl inosite, and the name dambose must be abandoned for the sugar derived from it. The abundance of dambonite in Gaboon caoutchouc naturally suggests the latter substance as the most profitable source of inosite. W. H. G.

On a New Class of Voltaic Combinations, in which Oxidizable Metals are Replaced by Alterable Solutions. C. R. Alder Wright. (*Jour. Chem. Soc.*, **51**, 672).—The author has made experiments in the construction of batteries in which platinum or carbon plates are immersed in communicating fluids capable of undergoing chemical reaction. In all cases, the plate immersed in the oxidizable fluid acquires the lower potential, the other the higher potential. The liquids are prevented from mixing by the interposition of some other liquid, through which the two must diffuse, the intermediate

reagent being placed in the bend of a **U**-tube, the limbs of which contain the other two, or in a beaker placed between two beakers containing the others, and communicating with them by means of cotton or asbestos wicks. Among the liquids mentioned, are: (A.) Solution of sulphurous acid opposed to potassium chromate and sulphuric acid solution, with sulphuric acid intermediate; this cell develops about 1·5 volt, and is constant. (B.) Sodium sulphite solution opposed to potassium permanganate rendered alkaline with potassium hydroxide. (C.) Chromium sesquioxide dissolved in sodium hydroxide, opposed to potassium bichromate and sulphuric acid solution. (D.) Potassium ferrocyanide opposed to potassium bichromate and sulphuric acid. (E.) Lead oxide dissolved in sodium hydroxide, opposed to an alkaline permanganate, hypochlorite or hypobromite. W. H. G.

THE PREPARATION OF CHLORINE, SULPHUR DIOXIDE AND OXYGEN IN KIPP'S APPARATUS.—Clemens Winckler (*Berl. Ber.*, **20**, 184) recommends the preparation of chlorine from chlorinated lime and hydrochloric acid in Kipp's apparatus. The chlorinated lime is first mixed with about one-fourth its weight of dry plaster of Paris, and the mixture is moistened and compressed. It is then cut into small cubes, and is ready for use. The hydrochloric acid, S. G. 1·124, is diluted with an equal volume of water.

G. Neumann (*loc. cit.* 1584) finds that sulphur dioxide may be readily prepared in the same manner, the materials being strong sulphuric acid and cubes composed of a mixture of three parts calcium sulphite to one part of plaster. For the preparation of oxygen, the cubes are made of two parts barium dioxide, one part manganese dioxide and one part plaster; the liquid is hydrochloric acid, S. G. 1·12, diluted with an equal volume of water; the oxygen will contain traces of chlorine, and should be washed through alkaline hydroxide solution. The cubes of the various substances are prepared and sold by Trommsdorff of Erfurt. W. H. G.

THE BOILING POINT OF OZONE AND THE FREEZING POINT OF ETHYLENE. K. Olszewski (*Monat. für Chem.*, **8**, 70).—Ozonized oxygen was led into a narrow tube cooled to — 181°·4 by boiling oxygen under ordinary pressure. The ozone then condensed to a dark blue liquid, and the tube containing it was placed in ethylene cooled by evaporation to about — 140°. It began to evaporate when the ethylene was near its boiling point, and the temperature of the ethylene when the ozone began to boil was — 106°. Liquid ozone is instantly decomposed with explosion by contact with combustible gases.

Ethylene cooled by boiling oxygen under ordinary pressure solidifies to a white, crystalline and almost transparent mass, which melts at about — 169°.
W. H. G.

THE BLUE IODIDE OF STARCH. F. Mylinus (*Berl. Ber.*, **20**, 688).—The blue color developed by the action of iodine on starch has been believed to be a simple addition product, or merely starch dyed by iodine. The author has examined the substance and determined the ratio of iodine to starch. The iodide of starch may be prepared from a clear starch solution, by the addition of a solution of iodine in potassium iodide; the blue liquid may then

be filtered without any solid matter separating. When sulphuric acid is added, the iodide of starch is thrown down and may be easily separated by filtration, and washed with water. The analysis of the substance dried in vacuum gave 18·47 per cent. iodine. Since the compound is very unstable, it was again analyzed without drying, as follows: a few cubic centimetres of the moist substance was treated with sulphurous acid, the fluid then becomes colorless, and after standing some hours, alcohol was added to precipitate all the starch. The latter was collected on a filter, dried at 120° and weighed; the filtrate contains hydriodic acid in which the iodine is estimated. Two analyses gave 19·65 and 19·69 per cent. of iodine; repetition of the method always gave between seventeen and nineteen per cent. The formula $(C^{24} H^{40} O^{20} I)^4$ HI would require 19·67 per cent., and this appears to the author the most probable formula.

Iodide of starch contains a hydrogen atom, which is replaceable by metal, and the metallic substitution compounds are formed when a solution of iodine in a metallic iodide is used in the preparation of the blue compound. Some of these compounds, as those of sodium and potassium, are soluble in water; others, such as the barium and zinc compounds, are entirely insoluble. Analysis of the barium compound is in accord with the formula $[(C^{24} H^{40} O^{20} I)^4 I^4]^2$ Ba. W. H. G.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, December 21, 1887.*]

HALL OF THE INSTITUTE, December 21, 1887.

JOSEPH M. WILSON, President, in the Chair.

Present, 143 members and twenty-six visitors.

New members, elected since last meeting, seventeen.

The following nominations for officers, managers, and members of the Committee on Science and the Arts were made.

For *President* (to serve one year),	JOSEPH M. WILSON.
For *Vice-President* (to serve three years),	W. P. TATHAM.
For *Secretary* (to serve one year),	WM. H. WAHL.
For *Treasurer* (to serve one year),	SAMUEL SARTAIN.
For *Auditor* (to serve three years),	LEWIS S. WARE.

For *Managers* (to serve three years):

WILLIAM SELLERS, CYRUS CHAMBERS, JR., HUGO BILGRAM,
G. MORGAN ELDRIDGE, HENRY R. HEYL, CHAS. HARE HUTCHINSON,
SAMUEL R. MARSHALL, CHAS. E. RONALDSON,

Members of the Committee on Science and the Arts (to serve three years): J. M. Emanuel, C. W. Howard, Prof. L. B. Hall, John Haug, Henry R. Heyl, Fred E. Ives, W. M. McAllister, Philip Pistor, H. Pemberton, Jr., Thomas Shaw, Louis H. Spellier, Prof. S. P. Sadtler, T. C. Search, W. Rodman Wharton, Otto C. Wolf, Moses G. Wilder.

Mr. GEORGE S. STRONG, of New York, presented a second communication on the "Strong Locomotive," describing some further improvements in the details of its construction, and giving a summary of tests of its efficiency made by Mr. E. D. LEAVITT. The paper has been referred to the Committee on Publications.

Mr. FRED E. IVES gave a brief historical sketch of the invention of what is known as the "Ether-Oxygen Lime Light." He described the several methods and forms of apparatus that had been suggested and put in practice for dispensing with the hydrogen element in employing the lime light for projection, and explained and exhibited an improved form of apparatus for carburetting oxygen, which he had devised. An abstract of Mr. Ives' remarks appears elsewhere in this impression of the JOURNAL.

Mr. WM. S. COOPER, by invitation, described and exhibited specimens of improved sanitary appliances of his invention and manufacture.

Mr. W. CURTIS TAYLOR showed, with the aid of the lantern, a photograph of a group of people, which was rendered most interesting from the fact that portions of the background—the frame of a door, the wicker-work of a chair, etc.—appeared in curious fashion upon the images of certain persons in the group.

The Secretary, in his monthly report, referred to the recent trials on a section of the Pennsylvania Railroad of the Westinghouse power brake for freight trains, and gave an account of the tests made with it, which appeared satisfactorily to demonstrate the great value of the Westinghouse system for the freight service of railways. The Secretary described and exhibited the operation of a life-saving apparatus devised by Mr. J. S. BADIA, and several useful products manufactured from the waste of oil-cloth, by processes invented by Mr. W. L. LANCE.

Considerable discussion was called forth by the offer of a resolution embodying a suggestion to erect an additional story on the Hall, in order to meet the pressing need for more space to properly accommodate the constant accessions to the library. The resolution was not favorably received.

Adjourned. WM. H. WAHL, *Secretary*.

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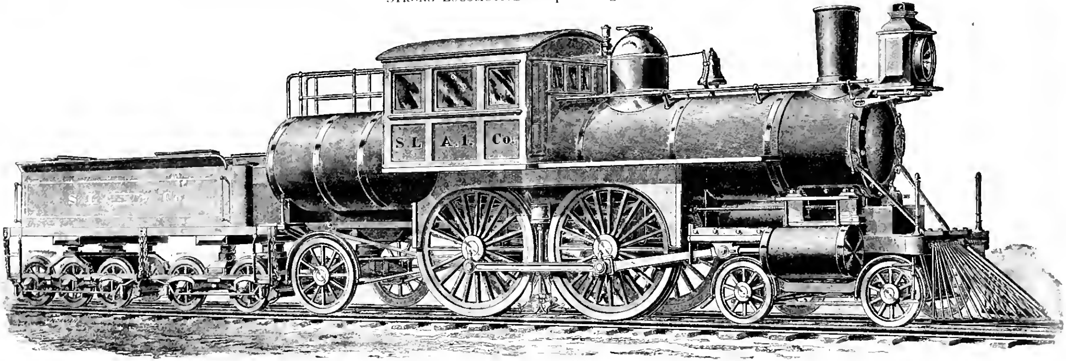
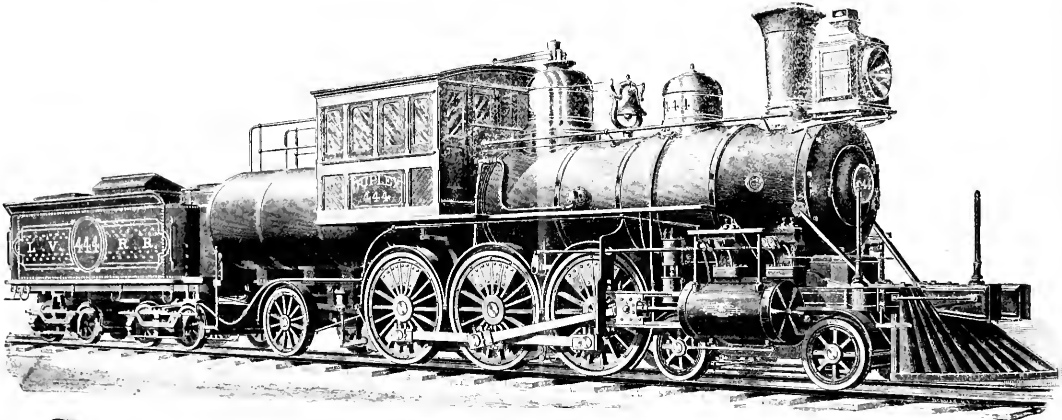
STRONG LOCOMOTIVE.—Express Engine.

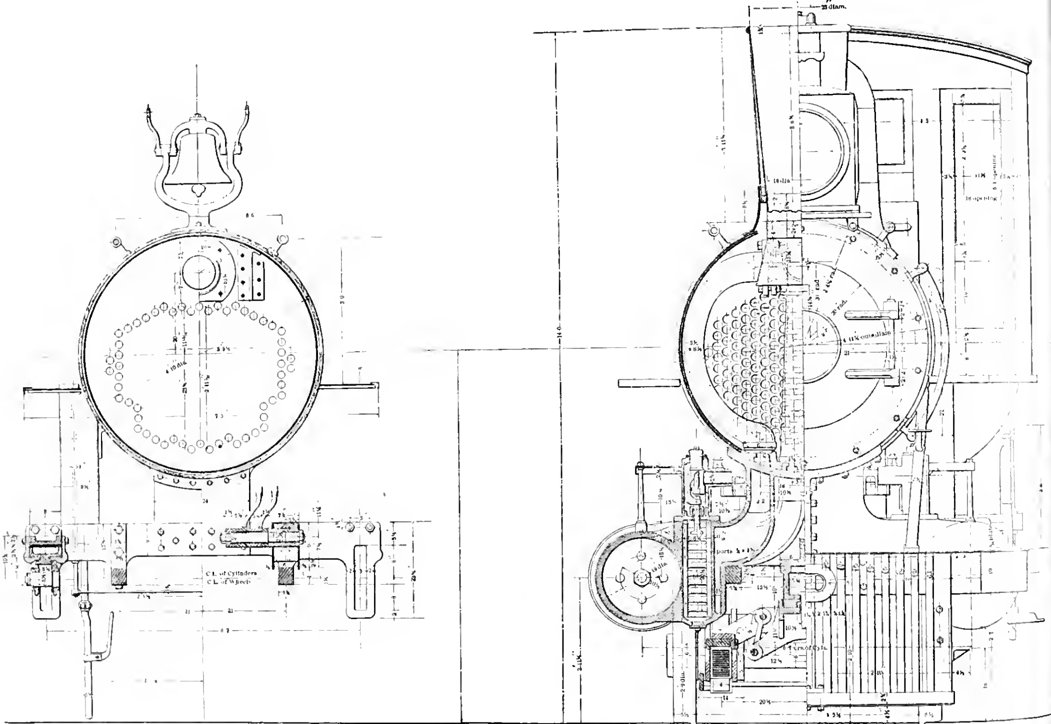


STRONG LOCOMOTIVE.—No. 444.



Jour. Frank. Inst., Vol. CXXV. Feb., 1888.

Sections of Strong Locomotive.



SECTION FRONT OF GUIDE YOKE, LOOKING BACK

SECTION THROUGH ROCKER BOX, LOOKING FORWARD.

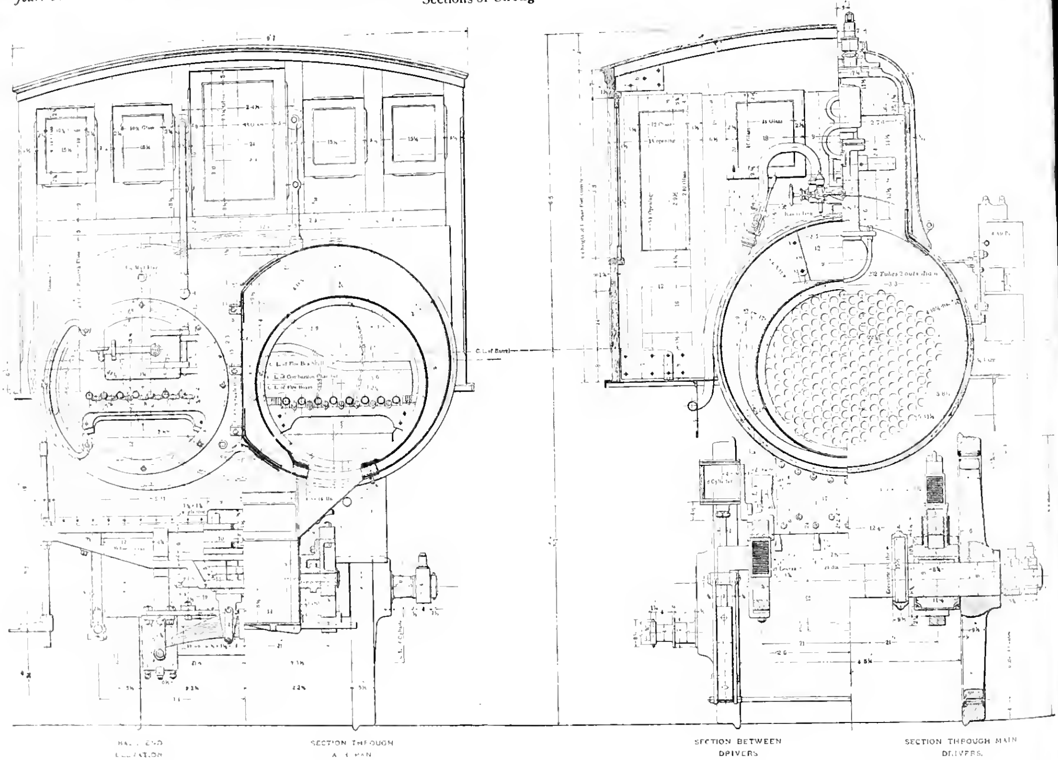
SECTION THROUGH CENTRE OF TRUCK AND FRONT INLET VALVE OF CYLINDER

FRONT END ELEVATION

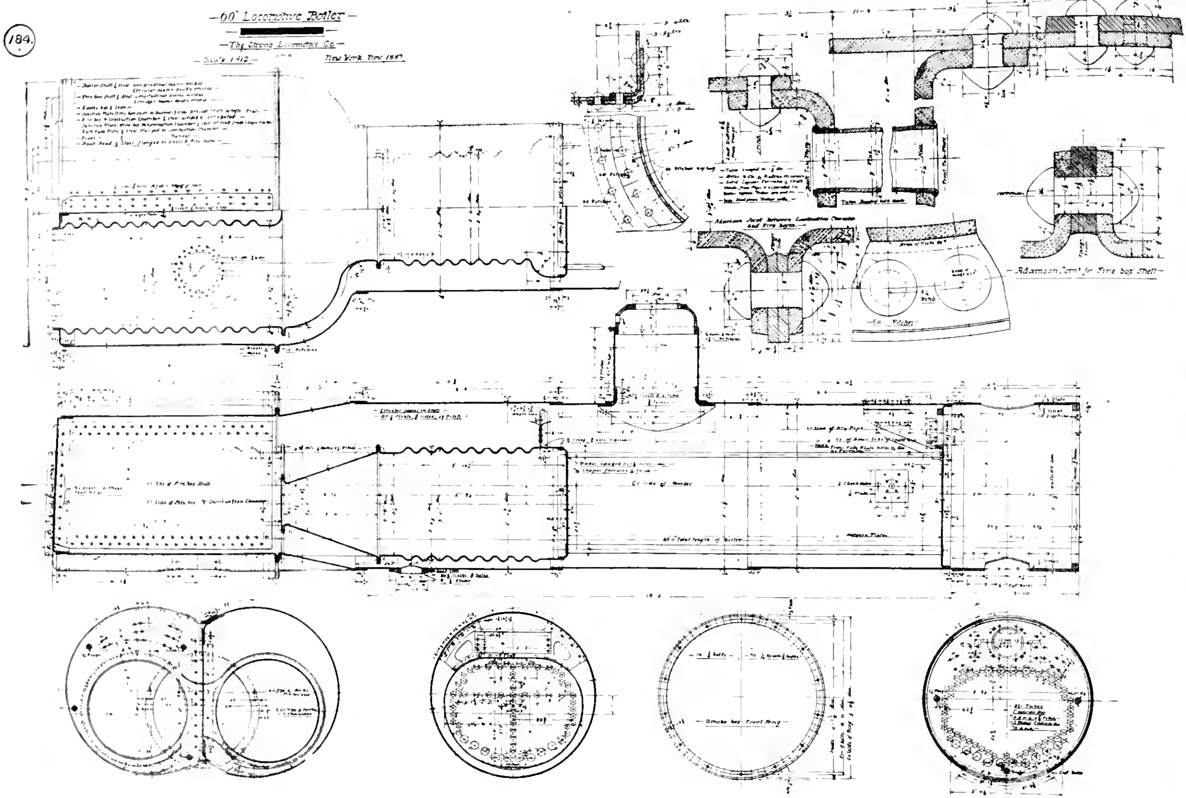
Jour. Frank. Inst., Vol. CXXI. Feb., 1888.

(Strong. Plate III.)

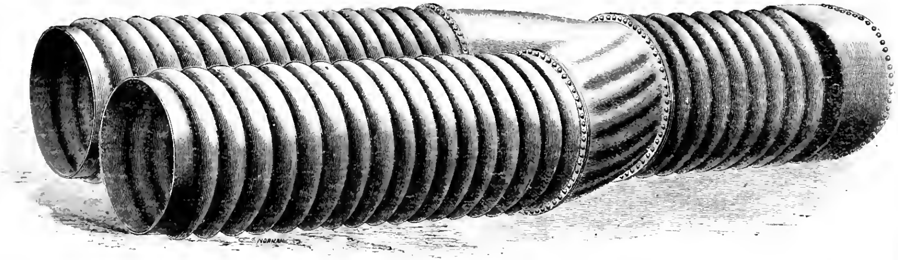
Sections of Strong Locomotive.



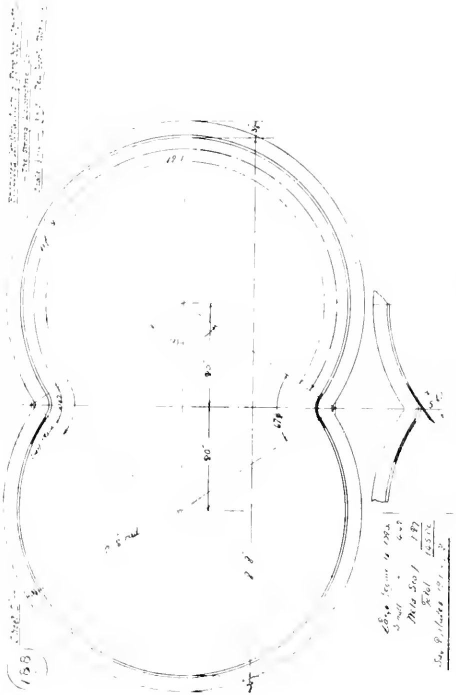
STRONG LOCOMOTIVE.—Section, Plan, Elevation and Details of Boiler.



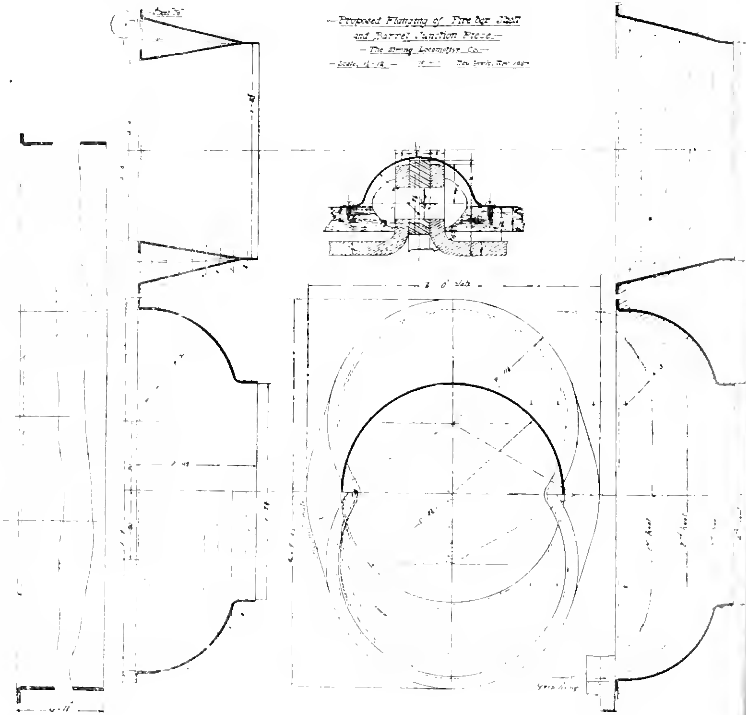
STRONG LOCOMOTIVE.—Corrugated Fire-boxes, Junction and Combustion Chamber.



Method of Forming Outer Double Shell.

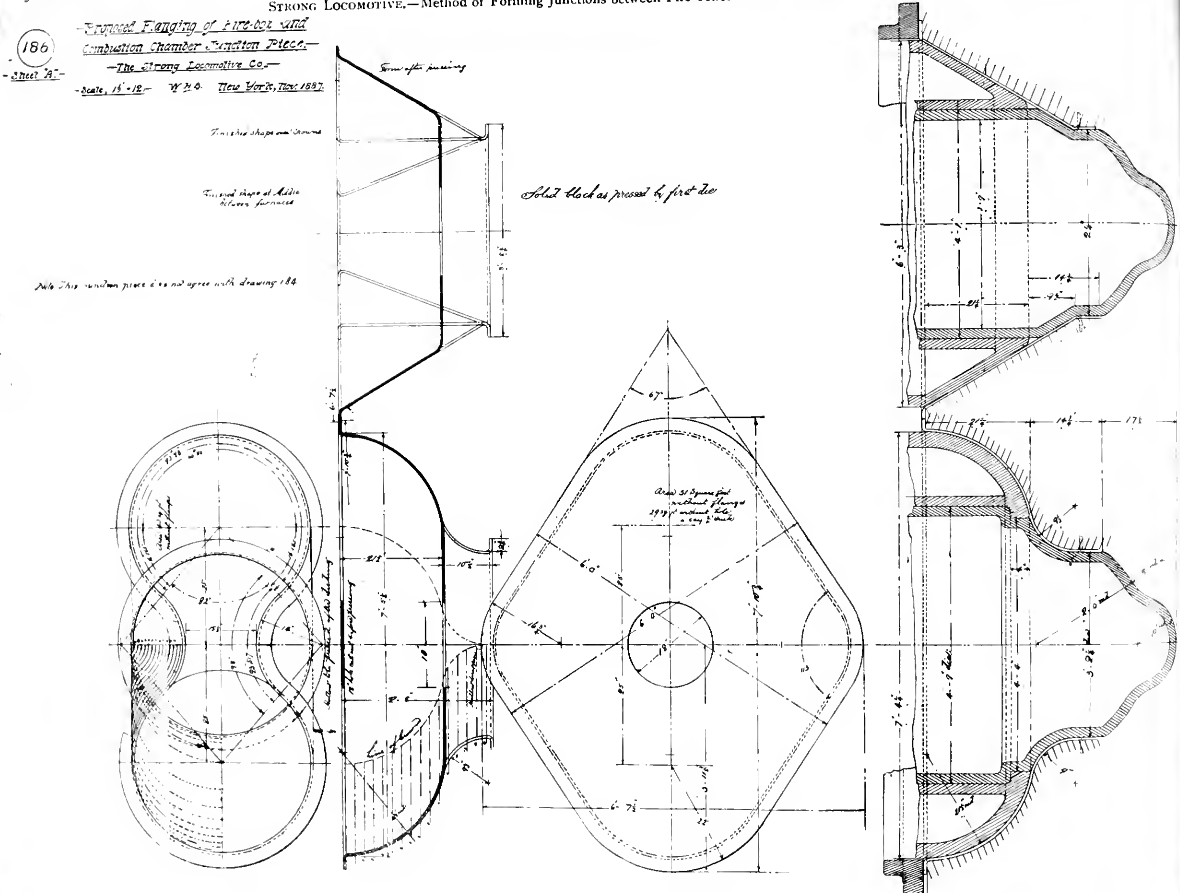


Method of Forming Junction between Outer Double Shell and Barrel.

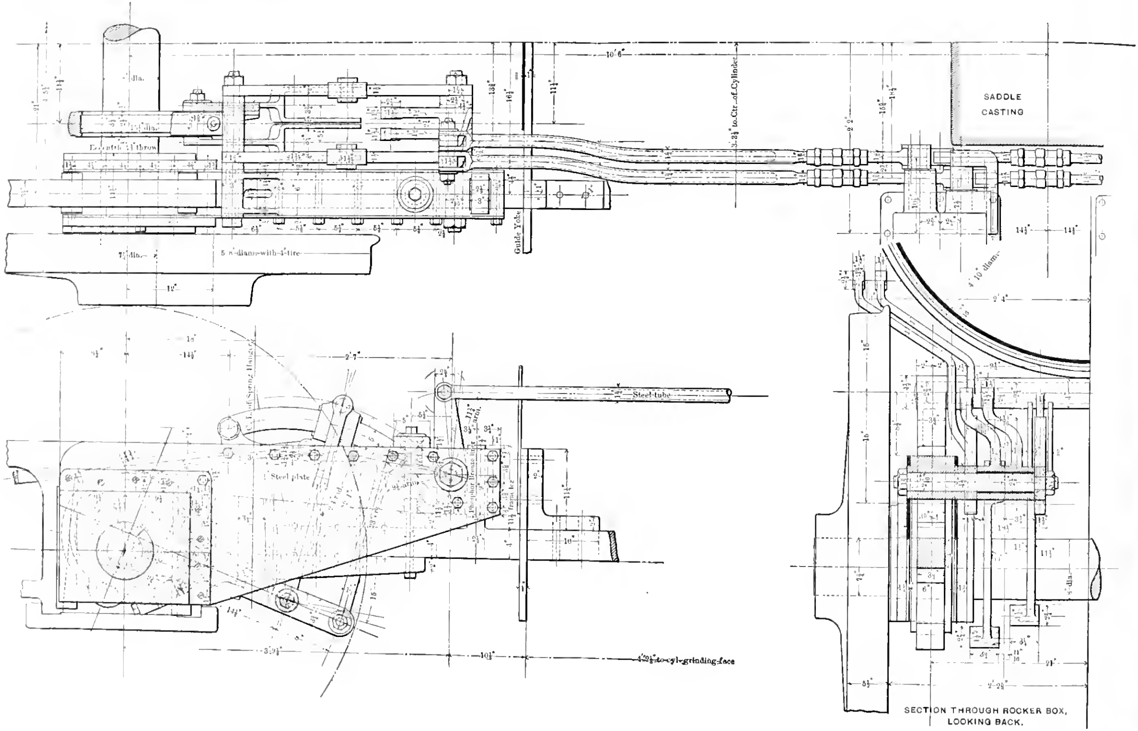


Jour. Frank. Inst., Vol. CXXV. Feb., 1888.

STRONG LOCOMOTIVE.—Method of Forming Junctions between Fire-boxes and Combustion Chamber.

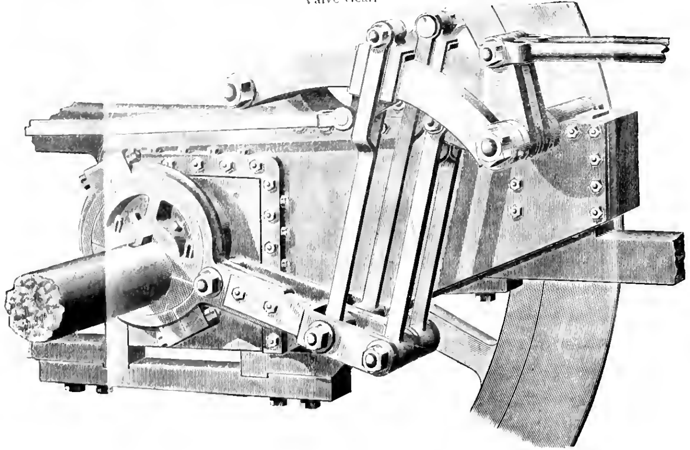


STRONG LOCOMOTIVE.—Elevation, Plan and Section of Valve Gear.

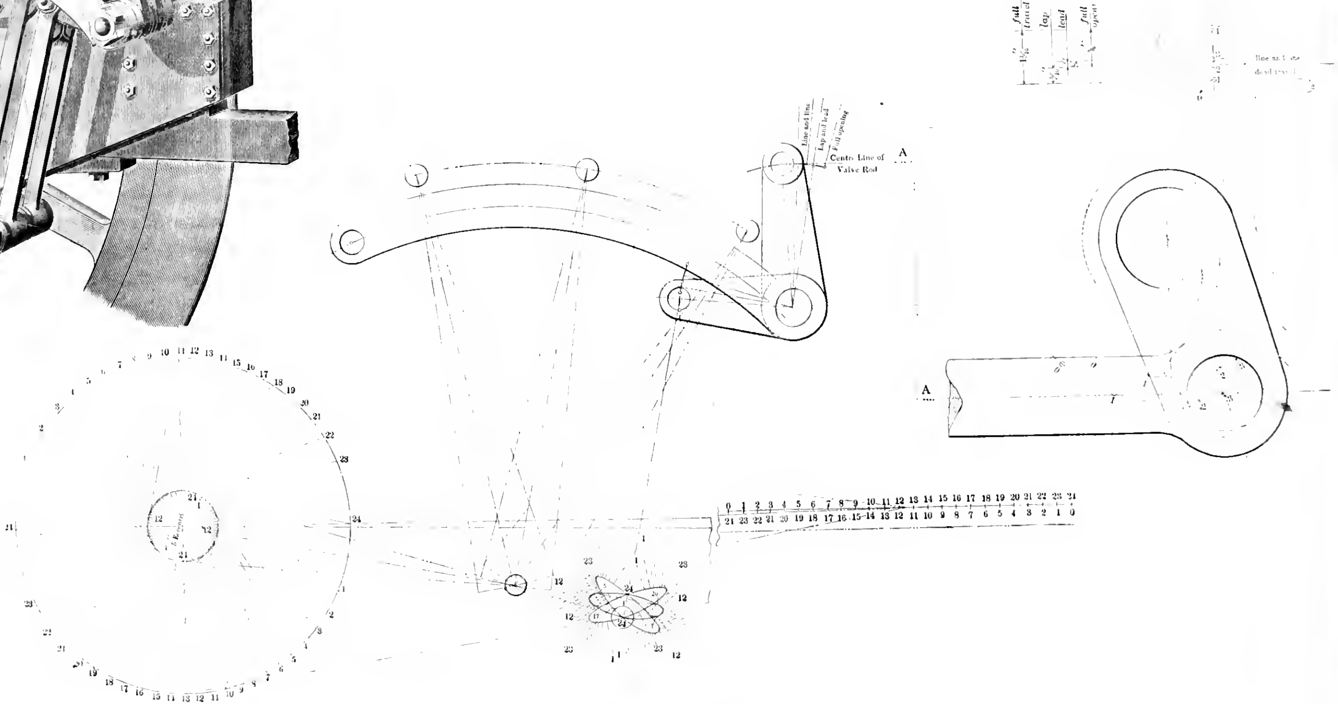


Jour. Frank. Inst., Vol. CXXV. Feb., 1888.

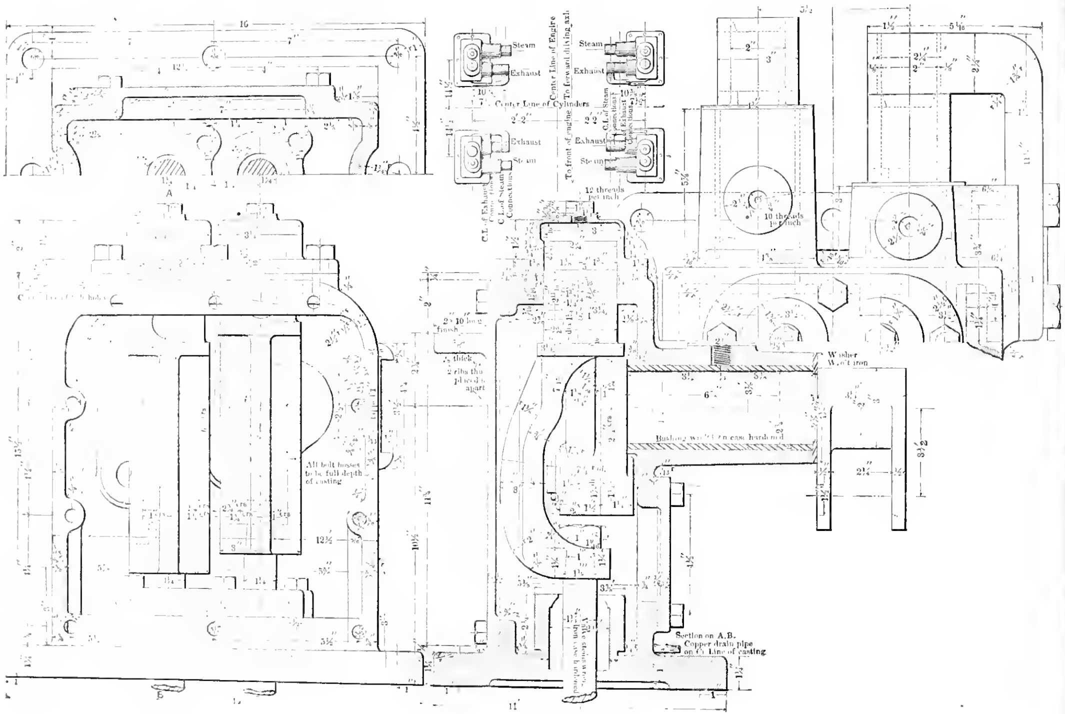
Valve Gear.



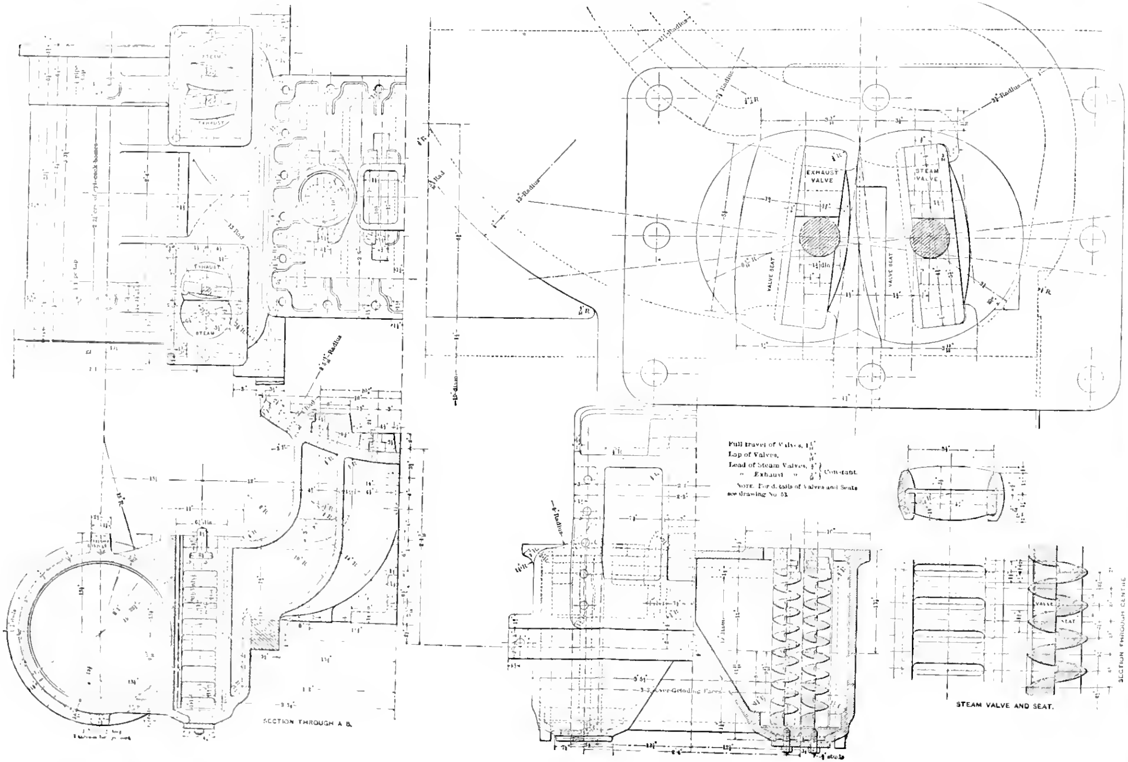
Strong Locomotive.—Diagram of Valve Gear



STRONG LOCOMOTIVE.—Section of Rocker-Box for Valve Gear.



STRONG LOCOMOTIVE.—Sections of Cylinder and Valve.



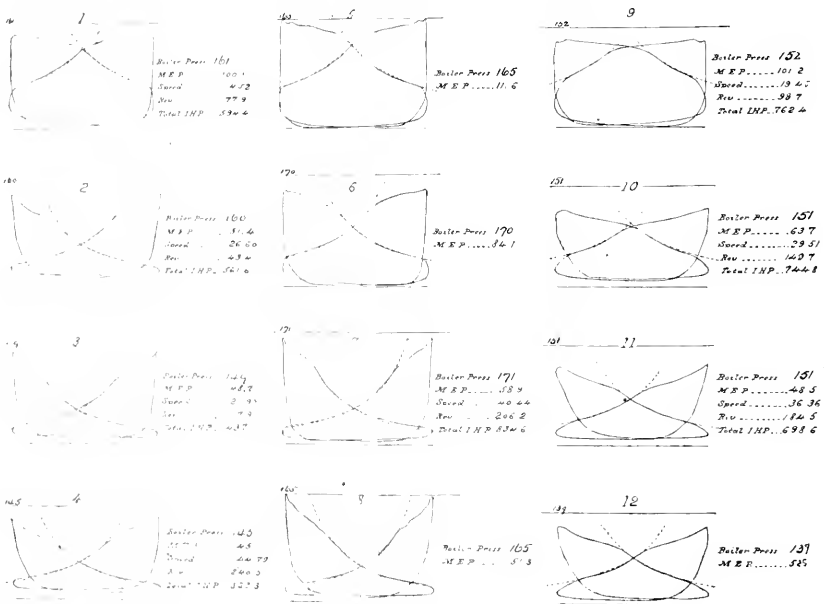
SECTION THROUGH A B.

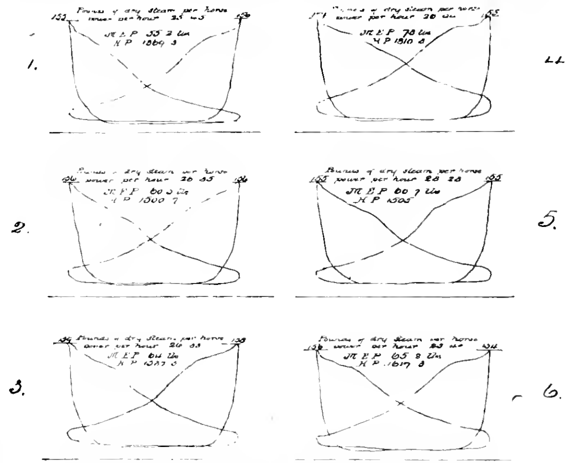
STEAM VALVE AND SEAT.

Locomotives 444, 383, 357

Indicator Diagrams.

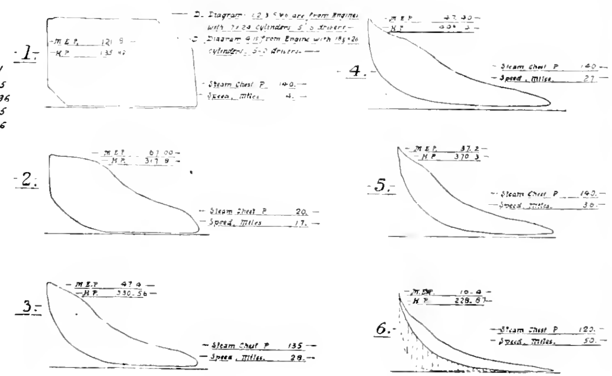
Scale 80 lbs to the Inch





Indicator Diagrams, Strong Locomotive.

Indicator Diagrams for L. B. and S. C. R. Engines
Fitted with Shifting Link Motion.
Scale 80 lbs = 1"



Indicator Diagrams, English Locomotive

JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXXV. FEBRUARY, 1888. No. 2.

The STRONG LOCOMOTIVE.

By George S. Strong.

(first paper.)*

Joseph M. Wilson, President, in the chair.

Mr. Strong:—This locomotive has been the outgrowth of a preconceived determination of its designer and inventor, to overcome the radical and well recognized defects existing in locomotives of ordinary construction, while retaining all the admirable qualities to be found in the running gear and minor parts.

Much discussion has taken place in the last few years regarding the possibilities of the future, as to fast train service, and much ink has been wasted, without any practical results, in stating what could and what could not be accomplished. It still remains a

* Read before the Franklin Institute, Wednesday, March 16, 1887.

fact, that there is no regular scheduled train to-day on the American Continent, or in England, or in Europe, that travels at a speed of sixty (60) miles per hour, for any considerable distance. We hear of fast runs being made occasionally, but when we come to make enquiries, we find that it has been with a very light train, or for a very short distance.

The *Railroad Gazette*, of February 11, 1887, speaking of a recent locomotive turned out by one of our Eastern builders, intended for very high speed, and in questioning the ability of the locomotive to do the work for which it was intended, says: *

"The locomotive in question is specially designed to run a train regularly at a higher speed than has ever been attained before. A speed of forty miles per hour, including stops, is a high speed on a first-class line, and is rarely attained for any distance in regular running. Special trains are, of course, often run at higher speed, but the rate of forty miles per hour, including stoppages, can only be maintained with any punctuality in daily running when the circumstances are favorable, the train not inordinately heavy, the grades and curves easy, and the average distance between stoppages at least thirty miles. When the train has to slack frequently at drawbridges or railroad crossings, such a speed cannot be maintained. The fact that such speeds are only attained by a very small number of trains in this country, shows the difficulty of maintaining a high velocity for a considerable distance. The fastest train on the New York Central runs from New York to Buffalo, 440 miles, in ten hours and forty-five minutes, or at the rate 40·93 miles per hour. This can be done because the grades are remarkably favorable, and the stopping stations average no less than 110 miles apart. The Pennsylvania runs the limited express from Jersey City to Pittsburgh, 443 miles, in eleven hours and seventeen minutes, corresponding to a speed of 39·27 miles per hour, the average distance between stoppages being 110·34 miles. The speed is fully one and one-half miles slower than on the New York Central, showing the effects of the more unfavorable grades and curves. On a straighter track, the Pennsylvania attains a considerably higher speed, the fastest train between Jersey City and Washington covering the distance, 226·7 miles, in five hours and two minutes, which gives a speed of

* This engine has since been acknowledged a failure, and has never run over the line intended for it. (S.)

45.04 miles per hour. The distance from New York to Boston by the Boston and Albany route is 234 miles, and notwithstanding the keen competition and great through travel, the speed is only thirty-nine miles per hour by the fastest train on this route, which covers the distance in six hours.

"The fastest runs in regular work between any two stopping points give a speed of slightly over fifty-three miles per hour. Higher rates of speed have been obtained when making up time, but at present the average speed while in motion seems to be considerably under sixty miles per hour. Many trains doubtless fully attain that speed on a large portion of the run, but the time occupied in getting up speed after starting, and slackening before stopping, reduces the average speed to about fifty-three miles per hour.

"These figures show the highest speeds attained on this continent for any considerable distance, and clearly demonstrate that the speed proposed on the New York, Providence and Boston, 62·5 miles in 62·5 minutes—including a stop at a drawbridge—is altogether exceptional in regular running.

"The principal peculiarity of the engine that is to run at this exceptional speed is the enormous weight on the drivers, 72,000 pounds. Why such a weight should be necessary to attain a high speed is somewhat of a mystery. Adhesion is very necessary to enable an engine to start a train or to haul a heavy train up a steep grade, but complaints about engines slipping at high speed are seldom heard. The difficulty is more generally the impossibility of getting the required speed out of the engine. In whatever position the reverse lever may be placed, the engine will not run to time. The reason has often been pointed out in these columns, and consists in the fact that at excessive speed the steam is so wiredrawn in passing through the ports that the steam line is attenuated, and sufficient pressure cannot be put on the piston to overcome the resistance of the train. The back pressure, too, is greatly increased, still further diminishing the size of the diagram. These difficulties can, however, be overcome in great measure by using slide valves with the Allen internal passage and large ports and exhaust nozzle. The more serious difficulty of making steam then remains, and can only be overcome by a liberal allowance of heating surface."

As to the question of the Allen valve being able to help them

out, the writer is led to believe, from experiments made with the indicator, and from the experience of some leading lines where this valve is used along with other valves, that little benefit is to be derived from its use, as it does not help the locomotive where it is the weakest, *i. e.*, on the exhaust side of the piston.

When we seek for the reasons we find that to run a very heavy train at a very high speed, for any considerable distance, takes a very large power, and a continuous development of that power. To obtain this we must have a very high mean effective pressure on the piston, and this must be maintained during the journey.

When we examine the link motion, we find it is not well adapted to give this high mean effective pressure without making a very heavy draught on the boiler. If we then go to the boiler, examine its construction and calculate its capacity for economical evaporation of the necessary quantity of steam from cold water, we find it is not well adapted for burning the large amount of coal required to evaporate this quantity of water. We also find that it is not well adapted to carry the pressure demanded. It is therefore evident that the boiler, valve gear and valves are found wanting, and that these are the vital parts of any locomotive. A high mean effective pressure is absolutely essential, and anything which tends to hinder the attainment of this is a weak point in the design or construction of a locomotive intended for heavy and fast train service.

The price paid in obtaining this much desired end must be carefully considered. This price consists of first cost, coal consumption, running expenses and maintenance of the locomotive and all its parts.

Let us see what are the necessary conditions to secure great economy of coal, steam of high pressure, and the use of this steam to the best advantage. There are certain well-known laws which control the production and burning of gases from coal, whether it be anthracite or bituminous, and if these conditions are complied with, complete combustion is as certain as the burning of gunpowder, or the combination of any elements which have an affinity for one another. If these conditions are not complied with, complete combustion cannot be expected. These laws are so well understood that it is hardly necessary to go into their explanation here; all that is required is, a grate of ample area to

first distil a sufficient quantity of gases from the coal, in a given time, to produce the necessary quantity of work. In a locomotive where 1,200 to 1,500 horse-power is required this cannot be done, as it could be in a gas producer, and a partial combustion goes on as the gas is produced; the grate, however, must be large enough to permit the coal to be burned on it without any being carried over and through the tubes. The second step and essential condition is the uniting of the gas so produced with a quantity of heated air large enough to cause complete combustion, and to maintain a temperature sufficiently high to ignite and burn the mixture of air and gas. Enough time must be allowed for a complete mixture to take place, before the gases or products of combustion go to the tubes in which combustion cannot take place, but where the heat generated by combustion is utilized and reduced.

In designing a boiler to meet these conditions, we have combined some very novel features, and have made use of the highest development of both the steel makers' and the boiler makers' art. This is emphatically the age of steel, and with it we entered on a new era in the art of boiler making, and the manipulation of steel plates. We are able to do things now, that a few years ago would have been regarded as impossible, and even now are so regarded, except by a few leaders who are always to be found with the courage of their convictions.

We have also taken advantage of well-known mechanical principles in designing shapes as near as possible to those that Nature would make, if she were undertaking work of this kind. That is, we have done away with all flat and square forms, to resist pressure by transverse strength alone, and have adopted those that give the greatest resistance against internal as well as against external pressures. We have also banished all stays and crown bars, and as a result we have a boiler that is not only strong, but one that will always remain so, and when finished and ready for work, will always be ready and not a constant source of expense and annoyance.

It will be readily understood from an examination of the accompanying illustrations, that the outer shell of the boiler is, as nearly as may be, the shape it would take if it were made of canvas, and then inflated. Therefore, under full working pressure it

is of the same shape as when it has no pressure on, and the metal in all parts of the shell is under direct tensile strains, there being no tending to bend the sheets. There can be no tendency to crystallize, and the parts should last as long as the natural life of the steel in other structures under similar light tensile strains, providing there is no corrosion going on. The factor of safety in the boiler illustrated is five.

The interior part of the boiler is so clearly shown as scarcely to require description. Departures from the ordinary construction call for a word of explanation: There are two fire chambers, discharging the gases generated in them over a hollow bridge, where they receive the supply of heated air necessary to cause complete combustion, and by alternate firing an incandescent fire is always maintained on one side to burn the gas from the opposite fire-chamber where coal has last been charged. The air which is to mingle with the gases is heated by the hollow grate bars and hollow bridge, and as a very thin fire is carried, air can pass up through it readily.

The fire chambers or furnaces are welded and corrugated steel cylinders, joined on to the combustion chamber by a welded and corrugated steel junction piece. This piece may be made of one plate formed on dies in a hydraulic press and flanged out to join the ends of the fire and combustion chambers, so as not to expose a single rivet to the direct action of the fire.

The combustion chamber is also a welded and corrugated steel cylinder, flanged out to receive a full-sized tube sheet. These internal parts are capable of standing eleven hundred (1,100) pounds per square inch external pressure. The longitudinal seams on the outer part of the boiler are all welded, and the circular seams, the only ones riveted, are united by a double row of rivets. It will be readily understood that we can safely carry almost any pressure, and the boiler shown is designed for steam of 175 pounds per square inch.

As we have shown how it is possible to construct a boiler to meet all the requirements of a very powerful and very fast locomotive, *i. e.*, maintain a very high steam pressure at a low cost for coal and repairs—let us see how the best use can be made of that steam, and in doing this we shall again make use of well-known mechanical principles.

It is a well-recognized fact in steam engineering that the best engine is the one that gives the highest initial and lowest terminal pressures, provided she is tight and is working up to her full capacity (*i. e.*, has a full load). To do this she must have a good admission, an early cut-off, a late release, a free exhaust, and a late closure of exhaust, with enough compression to bring the pressure of the confined steam up to that of the boiler at end of stroke.

Much has been written on this question of compression, and some have asserted that it was impossible to run a locomotive at a high speed with any less compression than that given by the link motion, but they have not taken into account the question of clearances. We have found that when clearances are reduced, compression must be reduced, and that with an engine having small clearances, a very small amount of compression answers every purpose, and that more will deaden the engine.

Here was a great problem to solve, and one that has taken years of careful experiment and investigation. We are required to produce an engine with independent steam and exhaust valves, which is at the same time simple, durable and practical.

Many attempts have been made before, and many failures recorded. Careful investigation soon satisfied the writer that the flat slide or gridiron valve was the only one that would answer the purpose. Valves of this kind have stood the test for years with high pressure steam in both stationary and marine practice; but to be a success, these valves must be allowed to come almost to rest while the load is upon them; wherever previously used, some form of cam or tappet motion had been employed to actuate them. In our first experiment we tried a device of this kind, but soon found that, with the rapid motion of a locomotive, it would not do at all. We then devised the very simple arrangement of rocker shown, which is so adjusted that after a valve has travelled its lap, it comes to nearly a full stop, while the corresponding valve at the other end of the cylinder is doing its work, and as the load comes upon the valve during this period of rest, there is very little wear. As the steam of compression comes up under the valve at its period of opening, there is a still further relief, while the exhaust valve does not move until it is relieved by expansion.

The method of introducing the valves and seats is clearly shown by the drawings. The valve seats are plugs, fitting in holes bored in the passages from the saddle to the cylinder, the ordinary steam-chest being dispensed with. The valves are let into grooves milled or planed in the seats, so arranged that the valves are free to move up and down in the seats.

There are ten (10) ports in each seat on a 19 x 24 inch, or a 20 x 24 inch cylinder, each port being 4⅝ inches, giving a total port length of 46¼ inches, in each valve. This length is also, of course, that of the lead line, as against the sixteen-inch of an ordinary locomotive. This arrangement, even when the engine is making 250 revolutions per minute, gives an initial pressure within two pounds of boiler pressure, and does not allow more than five pounds drop to the point of cut-off; while the ordinary form of valve will entail a loss of fifteen pounds between boiler and initial pressures, and another fifteen during the period of admission, making a loss of thirty pounds between boiler pressure and that at the point of cut-off; while under similar circumstances, we do not by any chance lose ten pounds. We cut off at four inches, and hold on to the steam until the last inch of piston travel, thus getting six expansions. The exhaust does not close until three and one-half inches from the end of the return-stroke, avoiding excessive compression. An ordinary locomotive loses thirty-three per cent. of the mean effective pressure from compression, which necessitates a late cut-off and not more than three expansions, in order to maintain the same mean effective pressure that we get with six expansions. Now it will be readily seen why the link-motion is not good for very fast and heavy work. It can neither get the steam in nor out properly. In losing at both ends, it exhausts at too high a pressure, and does not allow an initial pressure at all near that of the boiler. All these objections are entirely overcome by the valve-gear shown, which is of the radial type.

The motion for all the valves on one side of the engine is obtained from a single eccentric, one motion of the lever attached to the eccentric moving the valves, the amount of their lap and lead, and another motion produces the opening in addition to the lead. There are two levers worked from the same eccentric strap; one being bolted rigidly to it, while the other has a pin forged on

the end of it. This pin has a bearing in a bushed hole in the strap itself, at a certain distance from their ends. Both these levers have a fulcrum pin, connected with one end of a link, whose other end is hung by means of a pin from a block, capable of being moved along a sector or arc. The path of the pin when moved along this arc is radial to the fulcrum pin already mentioned. Thus the position of this block on its sector, which is regulated through the medium of a reach rod, by the lever in the cab, determines the inclination of the travel of the fulcrum pin. When the block stands in the centre of the sector, as shown on the drawing, there is no inclination to the travel of the pin, and the valve is moved only the amount of lap and lead. If, however, the block is moved forward on the sector, the fulcrum pin travels over an inclined path, which incline represents the opening of the valve in addition to the lead, and the engine moves forward, and if the block is moved forward to the end of the sector, the full travel of the valve is given, and steam follows the piston twenty inches of its twenty-four-inch stroke; if, on the other hand, the block is moved back past the centre, the path of the fulcrum pin is reversed, and the engine will run backwards. Thus it will be clearly seen, that by varying the position of the block on the sector, the travel of the valve is varied as well as the point of cut-off, which latter may be anywhere between four inches and twenty inches. In all cases the exhaust valve is allowed to travel its full stroke, and as it is worked by the lever having the pin forged on its end, and from a separate fulcrum pin, with an independent link, block and sector, its travel may be varied at will, and so, of course, may the steam valve. In ordinary working, however, the exhaust block is never moved on its sector, except for reversing, when both steam and exhaust-blocks are moved at the same time; after the engine is started, the steam valves are hooked up, but the exhaust is not disturbed. The steam valves are given one-eighth inch lead and the exhaust five-sixteenths inch.

(SECOND PAPER.)*

As the result of the trials of the Strong engine on the Lehigh Valley road, made in April and May, 1887, to develop the strong and the weak points of the engine, certain small alterations in detail have been introduced, which will considerably improve the engine as originally designed.

Of these alterations, one is the change in the method of riveting the seams in the furnaces. None of these are now made with the lap-joint, but instead, the Adamson flanged seam is employed. This is made by flanging outwards the cylinders forming the furnaces, combustion chamber and junction pieces, at right angles to the plate, and connecting the pieces thus flanged by rivets passing through each flange and an intermediate ring about five-eighths inch thick. This joint, therefore, exposes no rivet to the action of the fire, and nowhere is there a greater than a single thickness of plate between fire and water. Tightness and freedom from burning are thus secured, as well as strength and stiffness against collapse, for which the Adamson joint is so suited that it is almost universally employed in the great steam-using centre, Lancashire, England, as the furnace seam of Lancashire boilers which carry safely 100 pounds of steam, outside furnaces of three feet diameter, the joint occurring at every two feet, or 2 feet 6 inches. Another alteration in the boiler, is the welding of all the longitudinal seams. This operation, hitherto looked upon as uncertain, has been rendered completely safe by the introduction, into modern practice, of gas for all the operations of the forge and rolling mill. By suitable application of gas, surfaces to be welded may be heated to a proper temperature, and kept clean and free from dirt and scale. By this, there is a certainty in the welding operation hitherto unattainable, and sound welding, having the full strength of solid plate, may now be regularly effected. By this means, a boiler may be constructed in which all the waste of rivet heads and overlaps is avoided.

Further than this, as a riveted seam never has above eighty per cent. of solid plate strength, we effect a very large saving by welding, in the possible twenty per cent. reduction of plate thickness,

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* Read at the Stated Meeting of the INSTITUTE, Wednesday, Dec. 21, 1887. Being a Summary of the Results of Trials of the Engine on the Lehigh Valley Railroad, made by Mr. E. D. Leavitt; with comments thereon.

or, if we adhere to the same plate thickness, our boiler is twenty-five per cent. stronger than when riveted. By employing the Adamson seam also for the last seam to be riveted of the boiler shell, we are able to say that we have a boiler, every rivet of which may be closed by power, no hand work being required for any rivet of the outer shell. By a suitable design of the various connecting pieces of the furnace parts and outer shell, we shall in all future construction press these parts, which are of irregular form, from single plates instead as we are now doing from four parts, and by so doing will do away with any riveting or welding on these parts, as well as to save a large amount of stock, which is now waste in fitting these parts.

In present designs, there is a greater steam space over the furnaces than in the experimental engine, and the diameter of the boiler barrel has been increased to sixty inches, so affording larger steam space. Means also have been taken to utilize a portion of the waste heat of the exhaust steam to heat up the feed water, branch pipes being taken from the exhaust passages in the cylinder saddles and a portion of the exhaust steam led through a species of injector to combine with the feed supply to the boiler pump. The trials of the experimental engine have demonstrated the fact that, as a material for valves, cast iron is superior to steel, a set of steel valves tried for experiment having proved inferior to cast iron.

Since the reading of a paper on the Strong Locomotive before this INSTITUTE, in February, 1887, extended tests have been made on the Lehigh Valley Railroad, by Mr. E. D. Leavitt, of two locomotives fitted with the Strong valve gear, and of one ordinary locomotive. These engines were Nos. 357, 383 and 444. No. 357 was of the ordinary type ; No. 383 had the Strong valve gear ; No. 444 had both the Strong gear and the Strong boiler.

Engine No. 383 has an ordinary straight-top boiler, with fire box over instead of between the frames, and anthracite coal grates. Engine No. 357 has an ordinary boiler, similar to that on engine No. 383, but with a " wagon top " of eight inches, and the link motion, with plain slide valves having DeLancey's balancing device.

Annexed are the leading particulars of the three locomotives.

It will not here be necessary to detail the manner in which the tests were made. It is sufficient to remark that coal weights and water measurements were made with all the care and accuracy

customary in engine tests, and indicator diagrams were carefully taken with the Tabor indicator, and proper notes made of steam pressure and speeds, so as to insure the accuracy of the results obtained. In estimating the amount of steam consumed per indicated horse-power, as shown by the diagrams, the gross amount was first computed from the pressure in the cylinder, just before the opening of the exhaust valve. From this was subtracted the amount of steam remaining in the cylinder when the exhaust port closed. In each case, the volume of the clearances was taken into the calculation, and the result shows the net amount of steam consumed. To this, of course, it is necessary to add a certain percentage for cylinder condensation, in order to arrive at an approximately correct estimate of the water consumption per horse-power, which, of course, cannot be obtained from direct measurement of the cards. As, however, the percentage to be added cannot, in any case, vary appreciably in any of the engines from the same amount, we may take the card measurements of dry steam as representing pretty accurately the relative consumption of the various engines. Comparing on this basis No. 383 and No. 357, we find that an average of six cards from No. 383 show a consumption of 22·34 pounds per horse-power, and that a similar average from engine No. 357 shows 26·73 from five cards. The horse-power shown by these cards is for No. 383, 540·8, and for No. 357 is 380·2, the larger power showing considerably less water consumption. An examination of the cards shows that the link motion of engine 357, though of the best design, has the fault common to all link gears, namely, over-compression. From this the Strong gear is free, and the compression line in the cards of No. 383 show a marked difference from those of No. 357, especially, of course, at the earlier grades of cut-off. This reduction in compression greatly increases the area of the cards, and may have several results. First, it admits of earlier cut-off, and so saves steam for equal power developed. Secondly, for same point of cut-off it increases the mean effective pressure, and therewith the tractive power of the engine, so allowing of a heavier train at same speed, or of a higher speed. Generally it increases the efficiency of the engine as a motive-power, it enlarges the range of power, and increases the tractive force at high speeds per ton of weight.

It is true that by compressing the residual steam in a cylinder, we may render an engine more economical, but to this economical compression there is a limit, especially in locomotives. In a stationary engine, specially designed for certain work, we may fix our compression and proportion our cylinder accordingly, but in a locomotive which is required to work with fair economy through a very wide range of power, the conditions are very different, and in any case the great amount of compression given by the link motion at the earlier grades is unnecessary and harmful.

The cards from No. 383 show quite enough rounding of the lower corner of the diagram and compare most favorably with those from No. 357. It is equally noticeable that the cards from No. 383 show a much closer approach of the initial steam line to the boiler pressure than do those of No. 357, and the steam line is better maintained up to the point of cut-off, thus proving the great superiority of the Strong gear all round. This higher initial pressure is due to the great length of port opening given by the multi-ported or grid-iron form of valve, and the more defined cut-off is due to the peculiar arrangement of the rockers which actuate the valves and give a very rapid opening and closing of the ports. The final result is a card of large area and therefore a high mean effective pressure, which cannot be obtained with over-compression, and it is plainly visible from the cards 7 and 11, how, with a much earlier cut-off, a very much greater power is developed from No. 383 than from No. 357. All the cards shown were taken on up grades; the maximum being ninety-six feet per mile, between Sugar Notch and Fairview going south, and sixty-nine feet per mile going north between White Haven and Glen Summit. Though usual on the north trip to have a helper, none was allowed during the tests, so that the performance of each engine was accurately gauged. Each engine was made to run its best between the two points, hence the time spent by each upon this run may be taken as a good index of its capacity.

Taking the two fastest runs of Nos. 383 and 357 between Sugar Notch and Fairview, namely those on the 9th and 10th of May, the mean initial pressure of nineteen sets of diagrams is as follows:

No. 383, May 10th, mean boiler pressure, 159 pounds; No. 357, May 9th, mean boiler pressure, 151 pounds. These figures multiplied

by the tractive force per pound give for No. 383, $159 \times 131 \cdot 3 = 20877$, and for No. 357, $151 \times 149 \cdot 1 = 22514$; as the relative powers of the two locomotives. In other words, No. 357 should be 7·8 per cent. better than No. 383. Actually, however, No. 357 was 9·4 per cent. slower than No. 383. From this we can only draw the inference that the superior valve gear of 383 was nearly twenty per cent. more efficient than the link gear of 357. With boilers so nearly similar, the tests showed that the water consumption of 383 was 20·3 per cent. less than that of 357, and as the train loads were the same for each engine, it is clear that the superior form of the diagram from the Strong gear is to be credited with the difference.

The tests further developed the fact that No. 444 consumed very much less coal than either of the other engines, and this clearly indicates the superiority of the Strong boiler. The engineer of No. 444 kept the throttle partially closed, being generally rather nervous and unacquainted with the engine, and hence the water consumption was greater than it should have been. Notwithstanding this drawback, the work was done with 23·7 per cent. less coal than used by No. 357, and 8·7 per cent. less than that used by No. 383. Now, the cards from No. 383 are superior to those of No. 444, owing to the foregoing facts, and further to the fact that the blast nozzle of No. 444 was much too small and caused a heavy back pressure. It may then be fairly reasoned that, though No. 444 consumed more water than No. 383, she used less coal as a result of the new type of boiler.

In engines now constructing, we shall obtain cards fully equal or even superior to those of No. 383, and a boiler which will show an efficiency far superior to that of the ordinary type.

There is no reason whatever why the Strong boiler should be expensive to construct, for in place of the multitude of screwed stays and the riveted rectangular box with massive roof-bar stays, we substitute machine-made furnaces and combustion chamber, and abolish at a stroke all fire-box stays with their attendant labor and cost of repairs and maintenance. Our boiler has in fact the fewest possible number of parts, all formed by machinery and power riveted. Such a structure cannot but be stronger and cheaper than the old type of boiler which has such large surfaces exposed to transverse stress, for which thin plates are so unsuited, and hence

require the aid of screwed stays to resist by tension the steam pressure, which cannot possibly be carried by flat, unsupported plates.

The modern necessity for high pressures calls for some different form to resist such pressures than the rectangular stayed box, which contains within itself the elements of destruction, from the unequal expansion of parts heated to different degrees of temperature.

With acquired experience and in the light of modern methods of work and with modern materials and tools, it is time to depart from methods and types which were the best possible thirty years ago, when the locomotive was not developed to its present state of efficiency.

This thirty-years'-old practice we have been following until to-day. Without in any way reflecting upon the qualities of a machine which met the requirements of a generation back, in respect to speed and cheapness, it may be said that the time has arrived to make a fresh departure to meet present-day demands. We have now at our command the newer material, steel, which, whether forged or cast, is better than wrought iron for boilers, wheels, and moving parts generally. By the use of powerful hydraulic presses, steel plates of large size may be pressed into almost any form, and thus we can construct boilers well and cheaply, and containing few parts, few rivets or stays.

We have carefully worked out our locomotive and determined upon our standards for different classes of work, designing these standards so as to employ the greatest number of interchangeable parts, and each class is specially designed for its work with such proportion of parts and ratios of expansion, wheel diameter, piston speeds, etc., as experience and investigation have shown us to be suitable and economical. With these proportions once determined, and a sufficient number of standard types settled, it is a simple matter to manufacture locomotives of any class cheaply and well by the modern method of work. To-day, more than ever, are special tools employed in special work, machines designed for accurately and rapidly finishing any detail which, as it comes from the tool, is ready for the erector.

To follow out this system with our locomotive, we should employ a special machine for boring and facing up the cylinders, which,

with two settings, would not only do this, but also mill the frame recesses and bore out the valve-seat chambers, and generally leave the cylinder complete for its position in the locomotive. In a similar manner, at one setting, we may finish the frames, and generally, by a free use of the milling tool, drop press and steel castings, cheapen the cost of production very considerably. Indeed, the improvements in the manufacture of steel, both cast and wrought, have opened up a very wide field to the machinist and rendered possible methods of work hitherto out of reach.

The revolution in marine practice, effected by the introduction of the corrugated furnace, has not been greater than it will effect in locomotive practice, where the use of high pressure first commenced. Formerly very far behind, marine boiler pressure is now ahead of locomotive practice, which has remained practically stationary, but there is no reason why an advance should not now be made.

It has been shown by the tests made, that a horse-power may be obtained from 21·33 pounds of dry steam, and an evaporation of 8·56 pounds of water per pound of coal has been also shown from a feed temperature of only 64° to a pressure of 170. By means of the arrangement for heating the feed by a portion of the exhaust steam, an evaporation of 9·84 pounds from feed at 212° should be secured. Now with an evaporation of 9·84 and a pressure of 175 dry steam and as we have shown that a horse-power can be had for 21·33 pounds of dry steam or water evaporated into dry steam, which was found by actual measurement of the water used and not calculated from the card, we may safely count on a horse-power from $21 \cdot 33 = 9 \cdot 84 — 2 \cdot 16$ pounds of good coal per hour, as it has been shown by these tests that the re-evaporation takes up all the losses from cylinder condensation as accounted for by the card, and our water by measurement and by the card do not differ.

No. 444, when run on the Northern Pacific Railroad by an engineer who kept a fairly open throttle, developed at high speed over 1,800 horse-power, or over one horse-power from a square foot of heating surface, or thirty horse-power per foot of grate and a horse-power per every seventy-five pounds weight. She has boiler-power sufficient to hold out at this high speed indefinitely, and could do the same with a heavier train with a larger blast nozzle. No. 357 could probably not show higher than 764 horse-

LEADING PARTICULARS OF LEHIGH VALLEY LOCOMOTIVES, NOS. 357, 383 AND 444.

	ENGINE 444.	ENGINE 383.	ENGINE 357
CYLINDERS, ETC.—			
Heating surface, combustion chamber, square feet,	[illegible]	[illegible]	[illegible]
Heating surface, tubes, square feet,	1600,	1234·3,	1429·8.
Heating surface, total, square feet,	1848,	1385·9,	1572·1.
Ratio of heating surface to grate area,	29·8 to 1,	37·3 to 1,	40·1 to 1.
Smallest inside diameter of smoke stack,	16 ins.,		
Height of top of smoke stack above rail,	14 ft. 3 ins.,		
Working steam pressure per square inch,	160 lbs.,	160 lbs.,	140 lbs.
TENDER.—			
Eight-wheeled double trucks—Diameter of wheels,	33 ins.,		
Capacity of tender (gallons),	3,000,		
Capacity of tender (coal),	10,000 lbs.,		
Weight of tender loaded,	70,000 lbs.,		
(Same tender used on all tests.)			

LEADING PARTICULARS OF LEHIGH VALLEY LOCOMOTIVES, NOS. 357, 383 AND 444.

	ENGINE 444	ENGINE 383	ENGINE 357
CYLINDERS, ETC.—			
Cylinder, diameter and stroke,	20 ins. by 24 ins.,	19 in. by 24 in.,	$20\frac{1}{4}$ by 24 ins.
Diameter of piston rod,	$3\frac{1}{4}$ ins.,	$3\frac{1}{4}$ ins.,	$2\frac{29}{32}$ and $2\frac{31}{32}$ ins.
Length of connecting rod, centres,	8 ft. 3 in.,		
Transverse distance between cylinder, centres,	7 ft.,		
Distance from centre of main drivers to centres of cylinders,	12 ft. 10 ins.,		
Number of valves per cylinder,	4, 2 steam, 2 exh.,	4, 2 steam, 2 exh.,	One.
Type of valves,	Gridiron,	Gridiron,	Balanced slide.
Number of ports per valve,	10,	10,	
Size of ports,	$4\frac{5}{8}$ ins. by $\frac{3}{4}$ in.,		
Full travel of valves,	$1\frac{1}{16}$ in.,	$1\frac{1}{16}$ in.,	
Lap of valves,	$\frac{5}{16}$ in.,		
Lead of valves, steam,	$\frac{1}{8}$ in. constant,	$\frac{1}{8}$ in. constant,	
Lead of valves, exhaust,	$\frac{1}{16}$ in. constant,	$\frac{5}{16}$ in. constant,	
Throw of eccentrics,	$2\frac{1}{2}$ ins.,		
Tractive force per pound of mean effective pressure on piston,	154·8 pounds,	131·3 pounds,	149·11 pounds.
Cylinder clearance in cubic inches,	481,	448,	568.
Cylinder clearance in per cent. of piston displacement,	0·38 per cent.,	0·58 per cent.,	7·35 per cent.
WHEELS AND JOURNALS.—			
Driving and truck wheel centres (all tires of steel),	Wrought iron,	Cast iron,	Cast iron.
Front truck 4-wheeled swing beam,	Yes,	Yes,	Yes.
Rear truck 2-wheeled swing and radius bar,	Yes,	None,	None.
Nominal diameter of driving wheels,	62 ins.,	66 ins.,	68 ins.
Calipered diameter of driving wheels,	$62\frac{19}{32}$ ins.,	$65\frac{15}{16}$ ins.,	$66\frac{1}{4}$ ins.
Diameter of front truck wheels,	30 ins.,		
Diameter of rear truck wheels,	42 ins.,		
Total wheel-base of engine,	30 ft. 2 ins.,	22 ft. 9 ins.,	22 ft. 1 in.
Rigid wheel base of engine,	5 ft. 7 ins.,	7 ft. 9 ins.,	7 ft.
Driving axle journals (diameter and length),	$7\frac{1}{2}$ ins by 10 ins.,		
Front truck axle journals (diameter and length),	6 ins. by 11 ins.,		
Rear truck axle journals (diameter and length),	7 ins. by 9 ins.,		
Main crank pin journals (diameter and length),	5 ins. by 6 ins.,		
Coupling rod journals (diameter and length),	$4\frac{1}{4}$ ins. by 4 ins.,		
WEIGHTS, ETC.—			
Weight on first pair drivers, in working order,	30,000 pounds,		
Weight on second pair drivers, in working order,	30,000 pounds,		
Weight on third pair drivers, in working order,	30,000 pounds,	None,	None.
Total on drivers, in working order,	90,000 pounds,	74,640 pounds,	63,280 pounds.
Weight on front truck, in working order,	27,000 pounds,	24,880 pounds,	27,440 pounds.
Weight on rear truck, in working order,	21,000 pounds,	None,	None
Total weight of engine, in working order,	138,000 pounds,	99,520 pounds,	90,720 pounds.
BOILERS, ETC.—			
Heighth of boiler centre above rail,	7 ft. 3 ins.,		
Kind of boiler,	Twin Furnace,	Straight shell,	Wagon top.
Material for boiler plate,	O. H. Steel,	O. H. Steel,	O. H. steel.
Diameter of barrel inside smallest ring,	58 ins.,	55 ins.,	54 ins.
Diameter of fire boxes and combustion chambers, corrugated,	$38\frac{1}{4}$ ins. inside, $42\frac{7}{8}$ ins. outside,		
Length of grates,	9 ft. 0 ins.,	11 ft.,	11 ft.
Width of grates,	3 ft. 4 in.,	3 ft. $4\frac{1}{2}$ ins.,	3 ft. $6\frac{3}{4}$ ins.
Number of tubes, all iron,	306,	229,	248.
Diameter of tubes, outside,	$1\frac{1}{4}$ ins.,	2 ins.,	2 ins.
Length of tubes,	11 ft. 5 ins.,	11 ft. $4\frac{1}{2}$ ins.,	12 ft. 2 ins.
Grate area, square feet,	62 sq. ft.,	37·12 sq. ft.,	39·2 sq. ft.
Heating surface, fire box, square feet,	155,	151·6,	142·3.
Heating surface, combustion chamber, square feet,	93,		
Heating surface, tubes, square feet,	1600,	1234·3,	1429·8.
Heating surface, total, square feet,	1848,	1385·9,	1572·1.
Ratio of heating surface to grate area,	29·8 to 1,	37·3 to 1,	40·1 to 1.
Smallest inside diameter of smoke stack,	16 ins.,		
Height of top of smoke stack above rail,	14 ft. 3 ins.,		
Working steam pressure per square inch,	160 lbs.,	160 lbs.,	140 lbs.
TENDER.—			
Eight wheeled double trucks—Diameter of wheels,	33 ins.,		
Capacity of tender (gallons),	3,000,		
Capacity of tender (coal),	10,000 lbs.,		
Weight of tender loaded,	70,000 lbs.		

(Same tender used on all tests.)

power, which would make her weight per horse-power 118 pounds, and show only nineteen horse-power per foot of grate. No. 444, therefore, though with a large grate, shows a still larger power per foot of grate, which proves that the principle of the boiler with the extended combustion chamber is good. No. 383 also, though heavier per foot of grate than 357, owing to heavier general build, developed a horse-power for each 112 pounds weight and twenty-three horse-power per foot of grate surface, and this plainly shows the superiority of the Strong valve gear.

The complication of balanced valves and the difficulty in keeping them in order and tight has prevented their introduction, and we recently heard of a case where the steam consumption of the balanced valve was ten per cent. above that of unbalanced valve engines. With the Strong quadruple valves, all the advantages of balancing are secured without its complications, for, by the peculiarity of the motion given by the rocker gear, it is so secured that when the load on the valves is greatest, they are mostly at rest, and when they are moving, the compression coming beneath the steam valves so relieves them of load that they are to a large extent balanced, whilst similarly when the turn comes for the exhaust valves to move, they are exposed only to the pressure from the expanded steam. The fact that in actual work the wear of the valves is found to be almost *nil*, confirms these views and shows that the grid-iron form of valve, long successfully employed in stationary practice, has been wisely chosen, and that the use of four separate valves, each moving when needed, is better than one large valve, which is constantly on the move and with which a proper steam distribution is impossible. The question of balancing has thus been very satisfactorily settled.

The engravings herewith show clearly the various details of the boiler and valve gear, and the form of the indicator cards obtained from the different engines tested

The SOUTHERN ANTHRACITE COAL FIELD of PENNSYLVANIA—its ENORMOUS DISTURBANCES and CONSEQUENT PREMATURE EXHAUSTION.

By Henry A. Wasmuth.

The southern anthracite coal field forms a long, narrow synclinal (with occasional projecting fingers), extending from Carbon County to Dauphin County for a length of about sixty-five miles. The greatest width of the basin, a combination of minor rolls, is in the neighborhood of Pottsville—Minersville.

Messrs. Sheafer, E.M., at Pottsville, state the area of this coal field to be 93,440 acres, carrying a total thickness of coal of 102 feet, deposited in beds from three to twenty-five feet thick. The workable coal is estimated at twenty-five yards, of which probably two-thirds will go to waste and one-third will be marketed, the probable yield being 3,768,746,666 tons.

The fact that the strata of the southern coal field are distorted and dislocated by numerous longitudinal and transverse faults of more or less extent, has been established more than forty years. Where such faults have been intersected by cross cuts, no importance whatever has been given to them, because those in charge were unacquainted with the appearance of dislocating faults, and where longitudinal faults have been met with in the anthracite beds they have termed them "inversions."

The existence of "inversions" in coal beds has not been established in any part of the globe, for, whatever the condition of the measures and coal beds might have been—plastic or hard—at the time of their disturbance from the original horizontal position, their folding into shapes, as constructed by the mining engineers and geologists of the anthracite region, must have been accompanied by compressing the whole strata into a smaller space, which could not take place without more or less fracturing and dislocation of the strata. Geologist Rogers defined the character of longitudinal and transverse faults more than thirty years ago in accordance with the definitions of all authorities in Europe, and the imported notion

that the term "inversion" covers all information concerning longitudinal faulting, is based on total ignorance of stratification, and such notions must and have been disastrous to anthracite mining ever since; for the knowledge of the geometrical position of the mostly steep inclined anthracite beds is indispensable for laying out proper working plans.

In order to prove the existence of great disturbances of the anthracite measures, I will cite a number of occurrences.

The Williamstown Colliery, Dauphin County, controlled by the Pennsylvania Railroad Company, has been opened by a tunnel from the northern slope of Wiconisco Valley to Bear Valley (through Big Lick Mountain). The southern tunnel mouth is located in red shale with gentle north-dipping measures. About 400 feet north of the tunnel mouth a fault with south dip (contrary dip) is visible; its width is about ten feet, and it is filled with large pebbles and clay. The effects of this fault are similar to those of transverse faults.

The tunnel has intersected the series of the Lykens Valley coal beds; the main Lykens in an exceedingly fine condition.

About 1,000 feet north of the main Lykens bed, a longitudinal fault has been intersected by the tunnel; its strike is nearly parallel with the strike of the measures; its width is from a few inches to three feet and more, and it is filled with disintegrated and large fragments of rock; its bottom and top rock are polished and with distinct striation, thus indicating the course of movement of the broken strata.

The southern portion of the formation, viz., the part on the footwall of the fault, has slid down on the northern portion of the formation.

From the fault referred to, to the northern tunnel mouth, a distance of about 1,500 feet, all the strata are distorted and confusedly dislocated by at least three distinct faults. One of these faults is from one to six feet wide and is filled with clay and large bowlders of conglomerate. The main Lykens bed has been worked seven levels below the tunnel on an incline of from 20° to 45° north, and according to the parallelism of the strata, the Buck Mountain coal bed should have been intersected by the tunnel within 1,300 to 1,500 feet north of the main Lykens, but it has been intersected in a disturbed condition at about 2,200 feet.

The fault referred to will be struck on the incline of the main Lykens bed not very far below the seventh level at about the elevation of the tide line.

From this brief review of the strata intersected by the tunnel, it is unquestionable that only one great dislocation of the north-dipping coal measures has taken place, accompanied by consequent crushing, fracturing, etc., increasing towards the northern synclinal axis, a phenomenon similar to the enormous disturbances of the strata in the Panther Creek region.

The disturbance of the north-dipping flexure of the Mammoth bed in East Franklin Colliery was indicated more than ten years ago, and the colliery, with an additional outfit of new improvements, had to be abandoned on account of longitudinal faulting, etc.

Similar disturbances were indicated many years ago on the south-dipping flexure of the Mammoth bed in Lower Rausch Creek Colliery, and confirmed in the lowest western gangway. This colliery has also been abandoned.

Around Middle Creek Colliery there are indicated great disturbances of the strata, for east of Middle Creek (opposite the big rock) several adits have been extended towards the east on gentle north and south-dipping flexures of the Buck Mountain coal bed. Within a short distance south of these adits, the Buck Mountain bed crops out more than 150 feet above those adit levels, showing an incline of about 40° south. Is it imaginable that such sudden changes in the inclination of the strata within a comparatively short distance could have originated without disconnection and dislocation? and this phenomenon must have its origin in dislocation of the strata either by a longitudinal fault, or by a transverse fault with contrary dip.

The existence of another more southerly longitudinal fault is indicated by two old slopes in an almost vertical plane on the Mammoth bed and confirmed in the lower workings from the shaft. Of course, the phenomenon has been termed an inversion ever since.

The great dislocation of the whole carboniferous formation by a longitudinal fault in Otto Colliery was struck about forty years ago, but the phenomenon has been an enigma to geologists and the officers in charge ever since, and thus all of the improvements of t e old White Ash slope have been entirely wasted.

The topography of Panther Creek region is favorable to mining above water level, and the strata of both flexures of the narrow synclinal have been crossed by numerous adits. The *Second Geological Survey of Pennsylvania* has constructed this basin as a combination of several synclinals and anticlinals, but an investigation of only one cross-cut or adit on each flexure of the synclinal will be convincing that the strata of both flexures is enormously distorted by crushing, disconnection and dislocation by faults of both characters, and that there is no room for even a conception of the existence of the rolls constructed by the Survey.

The coal measures west of Tamaqua have not been crossed in their whole width so thoroughly as in Panther Creek, but from the enormously exposed disturbances in the latter region, from the numerous great distortions of the strata from Williamstown to Branchdale, and from the uniform general conditions of the whole basin, it must be concluded that similar disturbances of the strata exist from Tamaqua to Branchdale.

I venture to say, that in consequence of those great oblique dislocations by longitudinal faults, etc , the amount of workable coal is comparatively small below the elevation of the tide line in the southern field, which could be established pretty closely by sections through points where the longitudinal faults have been struck in the lowest gangways; for instance, Lower Rausch Creek, East Franklin, Middle Creek, Otto Collieries, etc., and such sections would also prove that the failure of Pottsville shaft with its long cross-cut is due only to lack of knowledge of stratification.

Furthermore, the marketable coal of the contents of the Mammoth bed in fair condition is estimated to be about thirty per cent., and it is therefore indubitable that the shipments of the contents of the distorted flexures of the bed, forming the main basin, and the flexure in Sharp Mountain hardly will exceed fifteen per cent. Of course, the flexures of the lower and upperlying beds will give additional shipments of uncertain amounts. But it is stated by the *Second Geological Survey*, that heretofore principally coal beds of six feet and more in thickness have been worked, and if the exhaustion of the finest coal beds on the globe has not been satisfactory to investors, as the expenses of mining towards the depth increase in geometrical progression, the question is at hand:

(1.) Is it possible that, by lack of knowledge of stratification the mine maps could represent the condition of the strata?

(2.) Could any estimate of the contents of coal beds, based on incomplete mine maps, be reliable? and must not those estimates referred to be greatly exaggerated?

(3.) In the face of the almost inexhaustible supply of cheap bituminous coal in Western Pennsylvania, is there any prospect of mining profitably at present prices the dislocated rolls of the series of coal beds forming the main synclinal?

I say, no, and feel assured that an investigation of the matter, by competent experts, which will of necessity be inexpensive, will thoroughly prove the truth of my statement, and at the same time convince those who are interested in anthracite mining in the southern coal field.

4128 Elm Avenue, Philadelphia, December, 1887.

STEAM BOILER TEST WITH DOWNWARD-DRAUGHT FURNACE.

By Francis E. Galloupe, M.E.

As a supplement to the investigation of Messrs. Lozano and Erben upon downward-draught furnaces, in recent issues of the Journal*, the appended report of a trial since made by the writer, in Boston, may not be without interest.

While it is not the writer's wish to criticise the investigation alluded to in detail, and while work of undoubted value has been done there in the analysis of the coal and furnace gases, some points necessary to the carrying out of the details of the tests in a proper manner seem to have been overlooked.

The first point to which attention may be drawn is the large percentage of refuse from the coal in the furnace at the end of the trials, amounting to twenty-seven per cent. in weight of the total coal burned in the first trial (ordinary furnace), and nearly twenty-seven per cent. with the downward-draught furnance. Deducting from the total coal burned (4,652 pounds) so large a quantity as 713 pounds as unburned coal, when this must have parted with

* Journal of the Franklin Institute for November and December, 1887.

some of its calorific power if put into the furnace at all, and deducting from the total (3,692 pounds) in the second trial, 417 pounds as unburned coal, gives percentages of unburned coal to total coal of 15·5 in the first and about 11·25 per cent. in the second trial. This would indicate of itself, by the smaller percentage, that the downward-draught furnace burned the coal up cleaner than the ordinary furnace, or else that less loss resulted with the downward-draught furnace from coal dropping through the grate, showing the water-tube grate to have been superior to the ordinary grate in this respect.

The second point which may be made is in regard to the water level. This varied from one inch height to four inches in the first trial, and from 1·5 to 4·5 in the second. For best evaporative work it should be kept as nearly constant as possible during the test; these variations may have been unavoidable, but are certainly not desirable. The admission that the water level was left one-half inch higher at the end of the second test "through inadvertency" makes the feed water record inaccurate, and no attempt appears to have been made to correct it for this difference of level, which might amount to 180 or more pounds of water. In ending a test, the water level in boiler should be brought to exactly the same height as at the beginning, and the steam pressure as near the same as may be possible in burning out all the coal in the furnace after the final charge.

It will be seen that in the following results a close agreement exists in some of them, while a considerable variation occurs in others; for instance, the percentages of ashes in the three trials are respectively, 14·1, 17·6 and 18·69 (refuse); the actual evaporation per pound of dry coal, 9·13, 8·47 and 8·42; equivalent from and at 212°, 9·61, 8·81 and 9·37; equivalent per pound of combustible, 11·19, 10·70 and 11·53, but the results are given without further comment.

TRIAL OF A TWENTY-FIVE HORSE-POWER VERTICAL TUBE STEAM BOILER, WITH DOWNWARD–DRAUGHT FURNACE.

Place and date of trial, East Somerville, Mass., December 14, 1887.

Duration of trial, ... 10 hours.
Weather, clear; barometer, 30·27; thermometer, 37, average; wind, light; direction, Southeast, velocity, 5 miles per hour.

DIMENSIONS AND PROPORTIONS.

Boiler, with box furnace, height,	6 feet.
Depth, inside, front to rear,	5 "
Tubes, 2 inches outside diameter, number 89, length,	5 "
Furnace. width, 3 feet 6 inches; length, 3 feet.	
Grate, 1-inch tubes; number, 21; length, 2 feet 6 inches; entering gun metal box at front, 6 inches wide; grate inclined 1 inch to 1 foot; underneath connecting pipes, 2 inches diameter; number, 6; inclined 2 inches to 1 foot.	
Air space through grate,	2·87 square feet.
Grate area, 3 feet 6 inches wide by 2 feet 6 inches long,	8·75 " "
Area in undertake to tubes,	3·50 " "
Area through tubes,	1·85 " "
Uptake to chimney, 16 inches diameter; length, 2 feet; area,	1·40 " "
Chimney, brick; size, 16 inches by 20 inches; area,	2·22 " "
Chimney, height above grate,	35 feet.
Heating surface in furnace,	70 square feet.
Heating surface in grate,	30 " "
Heating surface in tubes,	233 " "
Total heating surface,	333 " "
Square feet heating surface per square foot grate,	38 " "

RESULTS.

Steam pressure, by gauge, average,	60·5 pounds.
Temperatures, boiler room, "	67·5° F.
" outside air, "	41· "
" feed water, "	43·3 "
" water entering boiler, average,	132·5 "
Fuel, weight kindling wood, 46 pounds (= @ ·4, 19 pounds coal).	
Total coal,	1,070 pounds.
" equivalent dry Cumberland coal consumed,	1,089 "
" refuse, 200 pounds; percentage of net coal,	18·69 "
Total combustible consumed,	889 "
Dry coal consumed per hour,	107 "
" " " " square foot grate per hour,	10·22 "
Water, weighed, 9,273 pounds; corrected weight actually fed and evaporated,	9,169 "
Economic Evaporation. Water per pound dry coal from actual pressure and temperature feed,	8·42 "
Equivalent evaporation per pound dry coal from and at 212° F.,	9·37 "

Equivalent evaporation per pound combustible,	11·53	pounds.
Commercial Evaporation. Equivalent water evaporated per pound dry coal with one-sixth refuse, at seventy pounds gauge pressure, from 100° temperature, ...	8·36	"
Rate of Evaporation. Water, from and at 212° F. per square foot heating surface her hour, .	3·06	"
Commercial Horse-power. At thirty pounds water per hour, evaporated from 100° F. into steam, at seventy pounds gauge pressure,	29·57	
Horse-power, builders rating (sixty pounds steam pressure), ...	25·	
Hoise-power, per cent. developed above rating,	18·28	

It may be added that no attempt was made to obtain higher results than would be had in regular running, under ordinary working conditions, with good bituminous coal and good firing.

The results show a good evaporative performance, the equivalent, 11·53 pounds of steam obtained for each pound of combustible burned from and at 212° F. being something over one-half pound more than the average result of the Centennial tests, which was 10·99 pounds. The proportions of parts were not all that could be desired ; for instance, the uptake to chimney should not be of less cross-sectional area than that through the tubes. The chimney was not high enough to produce the best results. This is shown by the large percentage of refuse. With sufficient draught it would be possible to reduce this percentage from thirty-three to fifty per cent , and this saving would probably show in an increased evaporation per pound of coal. The damper in uptake was kept wide open throughout the test, and there was but little smoke.

The steam appeared to be of excellent quality and practically dry, and there was no priming. Most of the coal used was in lumps and contained too little moisture to be ascertained by weighing, after a quantity of it had been dried for nine hours. The water consumption was accurately obtained, and there were no leakages. The water level in the boiler was the same at the beginning and end of test, and the steam pressure within five pounds of the average pressure at both those points.

Boston, December 29, 1887.

The LIMITING NUMBERS of GEAR TEETH.*

By George B. Grant, Boston.

In the study of Kinematics, or the Theory of Pure Mechanism, there is no one subject that is as extensive and as intimately connected with mathematics, and few as interesting and important, as the theory of gear wheels. It is a favorite study with mathematicians, and has been extended and developed to a degree that is perhaps beyond its real importance in some directions.

In the theory of gear wheels there is no one item that is more difficult to handle, or that has been more befogged and complicated by the efforts of learned writers, than that of the limiting numbers of gear teeth.

Prof. Willis, perceiving the difficulty of a definite mathematical treatment, contented himself with a mechanical solution which can give but a rough approximation at best, and which is useless in extreme cases or for ordinary use and study.

Prof. MacCord, with commendable energy, has carried the work much further, and by a mathematical process has found and tabulated results that are generally reliable, although not as much so as claimed, but his methods are complicated and bewildering in the extreme, and require the most patient and laborious attention either to understand or apply. His results must be taken on his great reputation as a computer, unless the student has an abundance of time and energy to devote to their verification.

The bevel gear is not treated by either Willis or MacCord, and indeed it would require unusual courage to attack it by either of the methods they give. The recent introduction of machines for planing bevel gears with theoretically perfect teeth, gives to this enquiry a new importance, and necessitates a new and more available process.

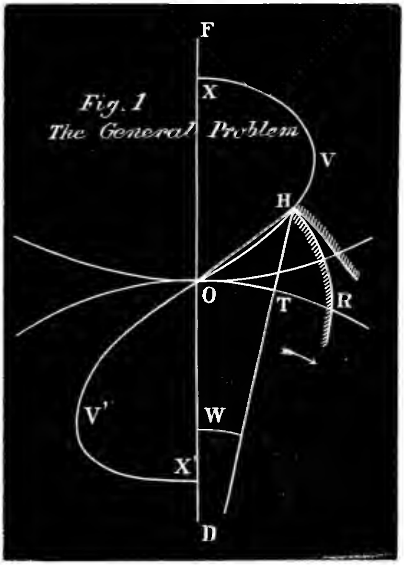
* In the *Scientific American Supplement* for May 7, 1887, I published an article on this subject; but I had not at that time applied the process to bevel gears or to internal gears. That paper will bear correction and improvement in several particulars. It contains matter, not in this article, relating to the non-interchangeable involute tooth, and to unreversible gears.

Neither author treats of the internal involute gear.

The following method is capable of being applied to particular cases with but little labor, as it requires nothing more than the substitution of the known data in the given formulæ. As the formulæ are all founded on the simplest rules of trigonometry, I will not take space to detail the processes by which they are obtained, but will simply explain them and give a few examples.

THE GENERAL PROBLEM.

When the number of teeth in a gear is small, it may leave contact with the mating gear before a required arc of recess has been taken up, and the problem is to find the numbers of teeth that will just take up the given recess.



In *Fig. 1*, which is drawn on the surface of a sphere, so that the gears are bevel gears, we have two gears, of diameters d and f, running together on centres D and F. The driver D, runs in the direction of the arrow, and drives the follower F.

The point of contact between the two teeth must travel along a certain line, $X' \ V' \ O \ H \ V \ X$, which is called the "line of action." The line of action for the approach need bear no resemblance to that for the recess unless the gears are to belong to an interchangeable set, and hence it is seen that the two actions have no neces-

sary connection, and that whatever may occur on one is independent of the conditions on the other. If the gears are to be interchangeable, both actions may have to be considered, but not otherwise, and for the present we will consider the recess alone.

In any limiting case, when a certain arc of recess OR, has been taken up, the point of the tooth must be on the line of action at H, and the direct object in view is to so determine the line of action that it shall meet the condition. When the line has been determined, the minimum number of teeth in the follower is determined by it by conditions that differ in each case.

To simplify the work, we will set the diametral pitch at unity, so that the circular pitch is π; we will assume the arc of recess to be a certain part of the pitch, as $a\,\pi$, and we will assume the thickness of the tooth, $2\,TR$, as $b\,\pi$.

The solution of the problem lies in the simple solution of a spherical triangle, for if we can determine the forms of four of the six parts of such a triangle, we can form an equation between them which will determine either part that is chosen as the variable.

In all cases we have

$$\textit{sine}\ O\,D = \beta = \frac{d}{2\,R} \tag{1}$$

and also the limiting angle

$$O\,D\,H = W = \frac{360}{d}\left(a - \frac{b}{2}\right) \tag{2}$$

but we can go no further without first fixing the form of the line of action and determining the system to which the gears belong.

In general, a gear will drive any gear down to a certain limit that is fixed by the given formula. It will drive any internal gear not greater than the limit with which it will not interfere. It will not drive a gear that is under the limit, but it can generally be driven by it.

It should be borne in mind that an internal gear is simply a negative gear. The difference between an external and an internal gear is simply a difference in sign, and not in kind.

It must also be borne in mind that the results for internal gears may be vitiated by interference. A three toothed gear will mathemetically drive a twelve toothed internal, as Willis claims, but he did not see that the curves would cross and interfere on the approach.

The difference between a spur and a bevel gear is simply a difference in size, from a mathematical point of view. A bevel gear is a spherical gear, and it becomes a spur gear when the diameter of the sphere becomes infinite.

THE CYCLOIDAL SYSTEM.

Bevel Gears.—In *Fig. 2*, which is drawn on a spherical surface, the line of action, $O\ H\ V$, is a circle; and that the flanks of the driven gear shall not be too much undercurved and weakened, it

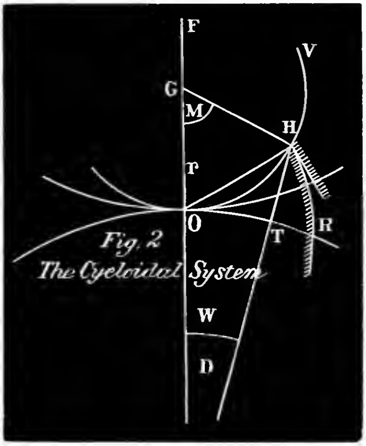


Fig. 2
The Cycloidal System

is customary to limit the diameter of that gear to a certain proportion of that of the circle of action, generally at not less than twice its diameter. We will set the diameter of the circle of action at q times that of the follower, or $2\,r = q\,f$.

This gives the angle,

$$H\,G\,O = M = \frac{360\ a}{fq},$$

and the side, $G\ O$; and, from the spherical triangle, $H\ G\ D$, we get the formula,

$$sin\ M\,cot\ W = \frac{d}{qf}(1-\alpha^2)+\alpha\beta\,cos\,M \pm (1-cos\,M)\ \sqrt{(1-\alpha^2)(1-\beta^2)} \tag{3}$$

in which

$$\alpha = sin\ GO = \frac{qf}{2\ R}$$

This formula, which may also be put in the form,

$$sin\ H\ G\ O\ cot\ O\ D\ H = sin\,(O\ D \pm O\ G)\ cot\ O\ G$$
$$\mp\ cos,\,(O\ D \pm O\ G)\ cos\ H\ G\ O$$

will solve any case in cycloidal bevel gearing; using the upper sign when the driver is external, and the lower when it is internal. The process for applying it to actual cases is the same as detailed below for spur gears, is not as laborious as the appearance of the formula would indicate, and I will not take space to cite examples.

Spur Gears.—If we put R equal to infinity, the bevel gears become spur gears; $\alpha = 0$, $\beta = 0$, and the formula is reduced to

$$\frac{sin\ (M \pm W)}{sin\ W} - \frac{d}{qf} \mp 1 = 0 \qquad (4)$$

which will solve any case in cycloidal spur gearing.

It is plain that this formula cannot be solved in general terms, for neither f or d can be separated by any process now known; but it can easily be solved, for any particular case that may arise, by a process of trial and error.

To explain this process, I will give one example in detail. Let the recess be three-quarters of the pitch, the tooth equal to the space, and the flanks of the follower radial; and let it be required to find a follower for an external driver of seven teeth.

This gives

$$a = \tfrac{3}{4}, b = \tfrac{1}{2}, q = \tfrac{1}{2}, d = 7,$$

and the formula becomes

$$\frac{sin\left(\frac{540^\circ}{f} + 25^\circ\,42'\ 51''\right)}{sin\ 25^\circ\,42'\,51''} - \left(\frac{14}{f} + 1\right) = 0$$

To solve this, put f at random, at 20, and by the trial, of which I give every figure to show its simplicity, the error is found to be positive.

$$\begin{array}{lcl}
\frac{540^\circ}{20} & = & 27^\circ \\
 & & 25^\circ\ 42'\ 51'' \\
\hline
 & & 52^\circ\ 42'\ 51'' \\
\hline
 & & 9{\cdot}9007 \\
 & & 9{\cdot}6374 \\
\hline
 & & 0{\cdot}2633 \\
\hline
 & & 1{\cdot}834 \\
\frac{14}{20} + 1 & = & 1{\cdot}700 \\
\hline
error = & & + {\cdot}134
\end{array}$$

and, therefore, 20 is too high.

Then, trying $f = 10$, it is found that the error is negative, and that the true value is therefore between 10 and 20, being nearest to 10. Trying 12, it is found to be between 10 and 12, and finally that it is between 11 and 12. If further accuracy is desirable, trials can be made between 11 and 12 in the same way.

When the follower is internal, f is negative, its flanks are reversed, and the circle of action is internal to the pinion, but there is in reality no change in the mathematical conditions.

From the same formula and by the same process, the driver is found when the follower is given, or the arc of recess when both gears are given. For an example, test MacCord's value of 382 as the least driver for a follower of ten teeth when recess equals the pitch and the follower has radial flanks. Trying 382, the error is negative; for 383 it is also negative, but for 384 it is positive; and, therefore, the latter is the true tabular number. If the formula be used to test MacCord's values for internal followers, the results will be found to agree very well with Willis's table, although it is not practically correct. The trouble with Willis's values is that his flanks are radial, and will, therefore, interfere on the approach, although they are mathematically perfect on the recess, for an internal follower cannot have radial flanks unless the driver is of at least half its diameter. MacCord should not compare his table with Willis's table, as he does, for he has dropped Willis's condition that the flanks shall be radial. According to Mansfield's law of internal interference, the circle of action in this case must be at least as large as the difference between the pitch diameters, and Willis did not have that law.

When either gear is a rack, the formula is reduced to

$$q\,f = \frac{2\,\pi\left(a - \frac{b}{2}\right)}{sin\ M} \tag{5}$$

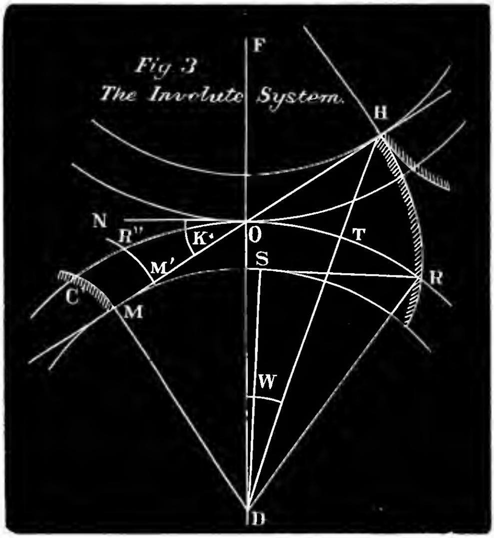
when the rack drives, and to

$$d = \frac{2\,a\,\pi}{tan\ W} \tag{6}$$

when it is driven, and these formulæ are to be applied in the same way as the general formula.

THE INVOLUTE SYSTEM.

Bevel Gears.—In *Fig. 3*, which is drawn on the surface of a sphere so that the gears are bevel gears, the line of action is a great circle $M\ O\ H$, and the teeth of the gears are involute in form.



In any limiting case, the point of the tooth must be upon the line of action at H, and the direct object in view is to fix the angle of obliquity, $N\ O\ M = K$, so that that condition is satisfied.

When the angle of obliquity has been determined, we can easily find the least possible driven gear from the known condition that the angle $O\ H\ F$ must be a right angle.

Draw $D\ M$ normal to $M\ O\ H$, and draw the base circle $M\ S$; lay off $R\ S$, equal to $O M$, and draw $S\ D$. $H\ O\ M$ is equal to $R\ S\ M$, and, as $O\ M$ is equal to $R\ S$, $H\ O$ must be equal to $S\ M$ The arc of the angle $M\ D\ S$ is equal to that of the angle $O\ D\ R$, and therefore

$$\text{angle } O H = \frac{180\ a \cos K}{R}$$

and from the spherical triangle $D\ O\ H$, we get the formula,

$$\cot W \cos K = \sin O\ D \cot O\ H \pm \sin K \cos O\ D \qquad (7)$$

from which the maximum value of the angle K can be found by the process of trial and error, as detailed for the cycloidal tooth.

Knowing the angle K, the follower is determined from the triangle $F\,O\,H$ by the formula,

$$f = \frac{2R \tan O\,H}{\sqrt{\sin^2 K + \tan^2 O\,H}} \qquad (8)$$

The upper sign is to be used when the driver is positive and external, and the lower when it is negative and internal.

But, when the recess is less than the circular pitch, it is not sufficient to fix the follower, as above, by the conditions on the recess alone, as can be done with cycloidal teeth. It is the universal custom to restrict the involute tooth to its interchangeable form, in which the angle on the approach is the same as on the recess, and, therefore, we must consider both actions.

The tooth of the driver cannot begin to act until its foot or cusp point arrives at the interference point M, and, therefore, the arc of approach cannot be greater than

$$O\,C' = O\,M \frac{\sin O\,D}{\sin M\,D} = \frac{O\,M}{\cos K}. \qquad (9)$$

But, it is plain that in any limiting case the action must commence at M' just at it ceases at H, and, as the whole arc of action, $R\,R''$, cannot be less than the circular pitch, π, and $O\,R$ is equal to $a\,\pi$, $O\,R''$ cannot be less than

$$O\,R'' = \pi - a\,\pi = \pi\,(1 - a). \qquad (10)$$

Therefore, the minimum angle of obliquity allowed by the approach, is given by the formula

$$\tan O\,D \sin K = \tan\left(\frac{\pi\,(1 - a)}{R} \cos K\right) \qquad (11)$$

Formula (7) will give a maximum value of the angle K, and (11) will give a minimum. It is plain that the maximum cannot be less than the minimum, and, that when they are equal, the corresponding driver is the smallest possible driver that can be used with the given recess.

Spur Gears.—When the radius of the sphere is infinite, the bevel gears become spur gears, and the formulæ can be adapted by making R equal to infinity. They can also be very easily derived by reasoning, which is so similar to that given for bevel gears that I will not detail it.

The adaptation of formulæ (7) and (8), gives the formulæ

$$tan\ K = \mp \left(\frac{a\,\pi}{d}\right) + \sqrt{2\left(\frac{a\,\pi}{d}\right) cot\ W + \left(\frac{a\,\pi}{d}\right)^2 - 1} \qquad (12)$$

and

$$f = \frac{2\,a\,\pi}{tan\ K}, \qquad (13)$$

which will solve any case in involute spur gearing.

It is to be noticed that this formula is direct, and that it is not necessary to work it by the process of trial and error.

But, if the follower is given and the driver required, we must work it by trial.

As explained in the case of bevel gears, the approach will fix a minimum value for the angle of obliquity, and this angle is given by the formula

$$tan\ K = \frac{2\,\pi}{d}\,(1 - a) \qquad (14)$$

By combining (12) and (14), we can get a value for d, which is the smallest involute interchangeable pinion driver that can be used with the given recess under any circumstances. Thus, when recess equals two-thirds of the pitch, we find that the smallest possible pinion has 5,300 teeth, and that no smaller gear will drive anything. This pinion will drive any gear not smaller than that determined by (12), and it will drive any internal gear that will not interfere with it.* Mathematically speaking, it will drive any internal gear, but when the two are of nearly the same size, the curves will cross each other, and the action will be impossible.

When the driver is a rack, formula (12) becomes

$$cos\ K = \sqrt{1 - \frac{b}{2\,a}} \qquad (15)$$

* Prof. MacCord states that the rack is the minimum follower for this minimum driver; see section 243 and the tables of section 276 of his *Kinematics*. It will, however, drive a much smaller follower; the one that is to it, as a is to $(1 - a)$. Thus, when recess is two-thirds the pitch, the minimum driver has 5,300 teeth and will drive a minimum follower having twice as many teeth. When recess is three-fourths of the pitch, the follower will have three times as many teeth, and so on. Prof. M. claims that I have here misrepresented him; but his language is plain, and will bear no other interpretation than that his tabulated followers are the least possible followers for the given drivers.

and, when the rack is driven, we have

$$d = \frac{2 a \pi}{tan\ W}, \tag{6}$$

which latter is identical with the same case in the cycloidal system.

On SOME EARLY FORMS of ELECTRIC FURNACES.

No. 2. DEPRETZ'S ELECTRIC FURNACES.

By Prof. Edwin J. Houston.

About 1849, Depretz, a member of the French Academy of Sciences, conducted an extensive series of experiments on the fusion and volatilization of different substances. During these investigations he constructed and used furnaces in which the intense heat both of the electric arc and of incandescense, was utilized for the treatment of highly refractory substances.

Depretz's researches were undertaken for the greater part to ascertain whether even the most refractory substances would not fuse or volatilize when subjected to intense heat.

In his earlier experiments he used the electric heat in conjunction with that of other sources; in his later experiments he used the electric heat alone. As a result of his experiments he announced to the French Academy on the 16th of July, 1849, that he had fused and volatilized magnesia and other refractory bodies, and that he had fused carbon. On the 19th of November, 1849, he announced the fusion of silicon, boron, titanium, tungsten, palladium and platinum.

Perhaps the most interesting portion of his researches related to the fusion of carbon, the results of which, for the greater part, are found in his "Fourth Note on the Fusion and Volatilization of Bodies," read before the Academy, at the Seance of the 17th of December, 1849.

In these experiments the electric heat, which alone was used, was furnished by a voltaic battery of 600 Bunsen elements variously coupled according to circumstances. The investigations were singularly complete; carbons from the most varied sources,

such as retort-carbon, carbon obtained from the calcination of sugar, or deposited during the decomposition of spirits of turpentine, anthracite, bituminous coal, graphite, and even the diamond itself.

The mode of application of the heat varied in the different experiments. In some cases the substance was simply placed directly in the voltaic arc, either while in a vacuous space, or while surrounded by an atmosphere of some inert gas. In most cases, however, the substance, in the shape of slender rods, was placed in good electric connection with two carbon holders, that formed the terminals of the battery before mentioned, and was thus raised to an intense electrical incandescence.

In some cases the substances to be exposed to the electric heat were placed in carbon retorts. The positive terminal of the battery was connected to the bottom of the retort, while the negative terminal, attached to a carbon of the same kind as that constituting the retort, was so held as to cause the voltaic arc to play directly on the carbon mass to be acted on by the electric heat. This, it will be seen, constituted an early form of electric furnace of an exceedingly efficient character.

We append the following translation, which we have made of Depretz's description of this form of furnace as contained in his communication of December 17, 1849, before referred to, and taken from vol. 29, of the *Comptes Rendus*, of July–December, 1849:

* * * * * * * * * *

"A small retort of sugar-carbon, about one and a-half centimetres in diameter, was heated by the pile connected in six series of 100 elements, until it was reduced to almost one-third of its volume. The bottom of the retort was covered with a mass of globules of the color of graphite.

"Another experiment did not give so many globules, but we found in one part of the bottom of the retort a bluish-gray plate of graphite as if formed by the union of several flat globules.

"The carbon points, which threw the light into the retort, as well as the holder which held it, were of sugar-carbon."

* * * * * * * * * *

"The two retorts had become soft to the touch, and had acquired the properties of graphite, without, at the same time being so easily made brilliant by friction.

"In these experiments, as in all those in which I had heated a body in a carbon retort, the retort was always made the positive pole, in order that the phenomena of transport could not interfere with the calorific phenomena."

Another form of early electric furnace was devised by Depretz in his experiments on the effect of intense temperatures on the diamond. In this form of Depretz's furnace the source of heat was solely that of electrical incandescence. The substance to be heated was placed in carbon tubes closed with corks of carbon, and the tube was then placed in the circuit of the electric source.

Depretz describes this form of furnace in this communication of December 17, 1849, the translation of which we append:

"As I have seen diamonds exposed suddenly to a strong heat, shivered into fragments, a fact also true for all precious stones, I previously heated the diamonds, which I wished to submit to my trials. For this purpose I shut them up in tubes of carbon of seven or eight millimetres in exterior diameter, closed by corks of carbon.

"In the first experiment, I placed a diamond about two millimetres in diameter, in a tube twenty-three millimetres in length between the two carbon holders.

"The pile was enfeebled by eight days' experiment. At first the tube reddened but feebly, and finally reached a white heat. The experiment was stopped after eight minutes. The diamond had become larger, and of a grayish-black like graphite. It conducted electricity, and left a trace on paper like graphite."

* * * * * * * * * *

"In the ninth experiment, I placed six small diamonds in a carbon tube seven and three-tenths millimetres in diameter, and thirty-three millimetres in length between the two holders. I had here arranged the pile in twenty-four series of twenty-five elements. The tube was immediately heated to a white heat and I stopped the experiment after seven and a half minutes. Already all the diamonds with the exception of two had been reduced to powder. This powder was without hardness, and marked the fingers and paper like graphite. One of the two diamonds not reduced to powder, immediately became brilliant like characteristic graphite."

Depretz's electric furnaces were, therefore of two types; viz.:

(1.) Those in which the substance was heated by the heat of

the voltaic arc aided more or less by the heat incandescence of the carbon retort in which the substance was placed.

(2.) Those in which the substance was subjected to the sole action of the heat of electric incandescence. It will be noticed that the electric source employed by Depretz, from the number of the elements it contained, placed at his command comparatively powerful electric currents.

No. 3. LONTIN'S ELECTRIC FURNACE.

In the two early forms of electric furnaces, already described, the heat of the voltaic arc or of electric incandescence alone was utilized. Although in the Pepy's furnace the chemical affinity of the heated iron for the carbon of the diamond, undoubtedly aided the operation, and permitted it to take place at temperatures probably far below those Depretz found necessary, and although, in some of the operations of Depretz, notably those in which the voltaic arc, formed between two carbon electrodes, was caused to play on the material to be treated, the chemical affinities of the electrodes were present, and, perhaps, to some extent aided the operation, yet, in neither of these early forms of furnaces, was such chemical action a leading or designed feature of their operation. They aimed at intense heat alone. They provided means for readily obtaining, in a limited space, an excessive temperature that not only permitted regulation as to its intensity, but entirely avoided the introduction of foreign gaseous or sublimed products into the furnace chamber, and thus permitted operations to be carried on that would be impracticable or difficult with furnaces of ordinary construction.

In the furnace of M. D. F. Lontin, we find a designed combination of electrical heat and electrical decomposition. The substances subjected to the operation were rendered electrolyzable either by electric heat or heat of extraneous origin, and were then subjected to the decomposing action of the electric current.

In the Lontin furnace the electric source employed was a dynamo-electric machine of the series type. The idea of the inventor was to place in the circuit external to the machine such a number of his electric crucibles as would by their resistance reduce the magnetization of the field magnets, and thus lessen the resistance to rotation of the machine.

Lontin took out letters-patent for his invention. The following descriptions are taken from his British patent No. 473, of 1875, for the "Application of electro-dynamic machines for obtaining metals, etc.," the provisional specification for which was filed on the 8th of February, 1875.

"It is well known that electricity decomposes metallic salts, and eliminates the metals therefrom, but according to this invention it is proposed to employ only electricity generated by electro-dynamic machines, and collected under the conditions hereinafter explained. Take, for example, an electro-dynamic machine, which, as is well known, generates electricity merely at the expense of motion. In these machines a portion of the electricity developed goes to magnetize the electro-magnets, and the remainder is at the service of the operator. If the proportion of electricity appropriated for magnetization be removed, or if the whole of the electricity produced be so applied (and this is the condition under which it is proposed to operate), the machine may acquire such a degree of resistance to rotation that it can no longer be kept in motion.

"The principle on which this invention is based is briefly stated as consisting in the employment of an electro-dynamic machine, wherein the whole of the current produced by the machine is returned to the primary electro-magnet (simple or multiple), in which circuit are placed what are herein termed the voltameters to be operated on.

"I will now explain the invention more fully. Suppose a break to be made in any of the wires of the machine, its power will thereupon cease, and if the broken wire be reunited, its power is again renewed. If, therefore, the circuit be completed by one or more apparatus, herein termed voltameters, the machine will work, and the substances placed in such voltameter will be decomposed, the resistance of the latter diminishing, to a corresponding extent, the resistance to the rotation of the machine. If now I employ as voltameters heated crucibles containing, for example, double chloride of aluminium and sodium, and two electrodes of prepared carbon, aluminium and chlorine are obtained.

"In these crucibles may be placed any metallic salt from which it is desired to obtain the metal, the completeness of the decomposition exceeding anything hitherto attained.

By the name of voltameters, I designate any apparatus in which are placed one or several chemical substances capable of being decomposed by electricity, and I designate by the name of dynamo-chemical an electro-dynamic machine employed in the manner above specified."

Lontin points out in another portion in the above patent the well-known fact that alternating current machines are unsuited to the work of electro-chemical decomposition, and that therefore commuted or direct current machines must be employed.

Though some of the ideas contained in portions of the patent are somewhat crude, when viewed in the light of to-day, they are nevertheless far from impractical. The similarity of some of these ideas to certain electro-chemical operations carried on to-day are too obvious to need comment.

In a later patent, No. 3,264, of 1876, Lontin claims the right of applying the current produced by other kinds of dynamo-electric machines than the series machine especially referred to in his former patent, as will be seen by the following quotation.

"I reserve the right of applying in all kinds of dynamo-electric machines the principle of sending all the electricity produced by one or more series of coils or induction wheels to the electro-magnets of the dynamo-electric machine, of introducing in a break in the circuit the apparatus in which the desired chemical or magnetic result is to be produced, the principle having been laid down in Patent No. 473, of 1875."

CENTRAL HIGH SCHOOL.

PHILADELPHIA, December 27, 1887.

A NATURAL SCALE AND MEASURE.

By John H. Cooper.

A rule for measuring and the divisions and subdivisions of it should be suited to the needs of the eye and hand.

The lengths of ancient measuring rods were derived from the length of the human arm, or part length of it, as, for instance, the *Cubit*—varying in length from seventeen and one-half to twenty-two inches—which is assumed to be the distance from the elbow to the tip of the middle finger, and the Russian *Arschine*, which is twenty eight inches long, or about the length of the full-grown human arm.

The common *two* and *four-fold* rules should not, in opened length, extend beyond the convenient reach of arm and sight, and the smallest subdivision of the unit upon them for general use should be plainly visible to the unassisted eye.

The standard inch as we now have it, as a fixed unit, should be preserved.

The conclusion is already foregone that the decimal system of graduating rules and scales should be employed and maintained.

In the adoption of the decimal system we shall merely change our usual way of thinking and saying small measures as now in sixteenths, thirty-seconds and sixty-fourths, and express them in tenths and hundredths, as stated by Whitworth, thirty years ago, to be "easy of attainment."

Whatever standard unit may be generally adopted, and however it may be divided, the subdivisions of it can be extended by instrumental means to almost any refinement of reduction by verniers and microscopes.

When the eye is assisted by optical devices, combined with exact mechanical adjustments, any degree of fineness that may be required by the most exacting practice can readily be obtained.

The millimetre is too coarse for a smallest division on the scale, and its subdivision into tenths would be entirely too fine for the eye; much finer than the hundredth of an inch, which is already practically invisible to most eyes. To subdivide the millimetre into halves and quarters would mix the fractional with the decimal systems and introduce confusion.

The human eye will in all probability ever be what it is now, and any scale suited to its present needs will always be right.

I propose taking for a unit of the scale, a space equal to one and a-half of the standard inch and divide this new inch into ten equal parts, subdividing each of these parts again into tenths, whence we will find the hundredth part of the new inch a plainly visible and practically usable quantity without the use of instrumental helps to the eye.

1 $1\frac{1}{2}$

A scale is here given, so divided in order that its least division may be seen in comparison with the standard inch similarly divided.

By the adoption of this scale we shall get rid of those uncertain approximations to the finer fractions, as "*a full 32d;*" *a 64th a little scant;*" and "*a 32d full scant,*" the smallest measure on the new scale being already reduced to the limit of distinct vision.

It is neither believed, nor urged here, that all the exact dimensions of the fitting parts of machines can be measured by the eye from this new scale, or from any other, nor is the substitution of measures by *sight* for measures by *feeling* here proposed for the extreme niceties of machine fitting.

The superior certainty of *feeling* over eyesight must ever, as is usual, without instrumental aid, remain as a means to be employed for copying minutest measures.

I propose further to use ten of these inches to make the new foot, which will be as long as fifteen of the present standard inches, and the new *two-foot rule* for general use will, therefore, be thirty inches long, which will make a measuring rod in every way more convenient for eye and hand than the Yard-stick, the Metre, or the Four-foot rule.

Philadelphia, October 7, 1887.

[*Contribution from the Department of Civil Engineering, University of Pennsylvania.*]

THE PHILADELPHIA TRACTION COMPANY'S CONDUIT.

BY JOSEPH C. WAGNER.

The question of rapid transit for Philadelphia has been agitating the public mind for years past. The growth of the city in population and in territory renders it more difficult each succeeding year for the horse-car companies to provide adequate means for the transportation of passengers through the city.

In 1882, the Philadelphia Traction Company essayed to provide for rapid transportation by introducing upon their lines of railway, the cable system of traction. It was thought that, although not securing as rapid rates of speed as is obtained upon elevated or underground systems, and though not having as great a carrying capacity as the two systems just mentioned, the cable would, at all events, partially solve the problem presented, and abolish many of the evils of the horse-car system. And all this at an outlay of much less capital than would be required by either an elevated or an underground system.

The cable system of traction for street cars was first introduced into this country in San Francisco, in 1873, on the Clay Street Hill Road. This road was but 2,800 feet in length. The favorable conditions of soil and climate made it a success, and led to its extension in that city, until at present several miles are in operation.

The cost in San Francisco of three miles of road was $155,698, exclusive of the cable and machinery necessary to run it These, together, cost $86,080, making a total of $241,778. The annual cost of running was $59,085, as against $138,880 by horse-power, being a saving annually of $79,795 for three miles = $26,598 per mile.

Chicago was the next city to make a trial of the cable, but its first line was not completed until January, 1882. The conditions at Chicago were much less favorable than at San Francisco. The ground there was soft and yielding, and the iron conduits could be prevented from sinking only by laying them upon heavy beds of concrete. One favorable condition in Chicago, however, was the absence of any considerable grades, the line being almost level.

The only hinderance then to the adoption of the cable system in the East was the question of its success in the Western cities, and the doubt as to its being able to withstand the rapid and varied changes in the Eastern climate.

The Chicago line, immediately after its construction, was thoroughly tested as to its ability to resist severe frosts and snow. It withstood the test very successfully, and there was no further bar to its extension in the East. The figures for the Chicago cable were considerably higher than those for San Francisco, because of the difficulties to be overcome in the soft nature of the soil. The cost per mile was $115,000.

The next city to adopt the system was Philadelphia, where the first line was built on Columbia Avenue, between Ridge Avenue and East Park, a distance of about two miles of single track. The mileage, at present, of the Philadelphia Traction Company's lines amounts to about fourteen or sixteen, and the company is still further extending its system.

The conduits on the Columbia Avenue and Market Street lines seem to have been put down with a singleness of purpose, and that purpose to have been that the cost of the road should be a minimum. The engineering requirements and conditions seem to have been utterly ignored, with the result too well known to all our citizens.

Some of the essential features of the conduit and method of laying, as employed on Columbia Avenue and upon Market Street, will be briefly described. In placing the conduit in its proper position, the cross ties under and connecting the stringers upon which rested the rails, were cut entirely through. This severed all connection between the slot and the rail and thus failed to fulfil two of the most important requirements of the conduit, viz: that the gauge of the tracks should remain constant, and that the system should possess "sufficient rigidity to resist displacement by water, frost, travel and other forces." The road in this faulty condition worked well enough until frost set in. The ground being moist and suddenly freezing naturally expanded, and in consequence a great pressure was brought on the sides of the conduits, which had not sufficient stiffness to resist bending. The slot was consequently almost, and in some cases, entirely closed, so that the grip could not pass between the two edges. The remedy first

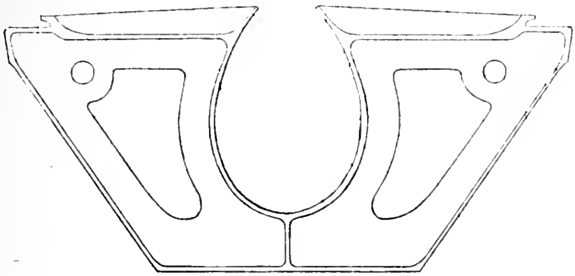
applied was an iron rod, bolted to the upper part of the conduit, running through the string pieces and bolted upon the outside of these. But this availed nothing, and was but useless expense, for the defect was not yet remedied. There was as yet no adequate provision for counteracting the pressure to which the conduit was subjected. The cross ties were not ties, but merely served as foundations for the stringers, and each succeeding frost gave fresh evidence that the gauge of the track could not be maintained constant by the means provided. In consequence of the contraction of gauge, some fifty car axles were broken during the preliminary trips. This tension rod having become inadequate properly to maintain the gauge, other means were sought, and the second proposed changes were of a more scientific and effective nature. The old cut ties were removed and replaced by new ones, one end of the new tie abutting against the upper part of the conduit, and the other end extending beyond the stringer and provided with an iron shoe. An iron rod twice as thick as the old one was bolted to the upper part of the conduit, and, passing obliquely through a hole in the stringer, was bolted to the end of the tie itself, resting on the iron shoe fitted on the end of the tie. The ties being of wood will soon become inefficient on account of rotting, and will have to be renewed. This renewal will have the disadvantage of causing a movement of all the connected parts, thus breaking, for the time, the continuity of the structure. The parts, too, are so situated as not to be easily accessible for repair. The new ties were placed four feet apart. Soon afterward the system was still further braced by the introduction of a tie bolted to the bottom of the conduit and running obliquely up to the upper surface of the new tie. This triangular system of bracing thus formed is undoubtedly " the cheapest and most effective that could have been substituted." The slot itself, however, as amended, does not yet seem to be of sufficient strength to resist the effects of the heavy traffic over it. The shape is faulty and likewise the manner of holding it in place, there being nothing but a single bolt near the end of the lower angle. The thickness of the angles of the slot is too little and the angles themselves are too long to possess sufficient rigidity to resist any great force coming upon them.

The man-hole covers already put down have given evidence of faulty construction. Sufficient allowance for heavy traffic was not

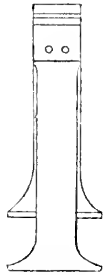
made, and, in consequence, many of them have become warped and unfit for use. Large numbers of these covers have been replaced by new ones of greater thickness. These improvements to a system initially defective, have necessitated an outlay of some \$250,000. The initial cost of the road was between \$40,000 and \$50,000 per mile.

The San Francisco and Chicago systems differ entirely from the system at present in vogue in Philadelphia. The Traction Company is now extending its lines on Seventh and on Ninth Streets, south of Market. The plant there used, however, is widely different in all its parts from the old plant. The new system is patented, but it is practically the same as that used in Chicago. It is in fact an alteration of the Chicago system, without being an infringement on the plan. The conduit consists of a tube of sheet iron ⅛ inch thick and 4 feet 5½ inches in length, bent into a particular shape. The tube is supported by, and bolted to, iron yokes placed 4 feet 6 inches apart between centres. (In the Chicago system the yokes are 8 feet apart.) These yokes are placed with great accuracy, an error of ⅛ inch not being allowable. The yokes rest on beds of concrete about 6 inches deep, and there is a concrete filling around the tubes between yokes. To the yokes are bolted the slots and rails, which are of steel and of peculiar cross section. The slot is bolted to the shoulder of the yoke. Each rail and slot is 31 feet in length. At every 31 feet 6 inches there is a single man-hole, one side of which is similar to one half a yoke, the other side being of special design. Within the man-hole 5 inches below the conduit proper, and on each end of the man-hole, there is a projecting shelf upon which is bolted two channel bars. These channel bars are placed on one flange with the flanges extending away from the centre line of the conduit, and run parallel to this line. Upon these is bolted the pulley and its attachments, over which runs the cable. At every square there is a double man-hole, or "grip-hatch," so called, which extends on both sides of the conduit proper, and is essentially a single man-hole on each side of the centre line of the conduit. These man-holes lie between the track and the slot. The ends of the man-holes take the places of two yokes, supporting the tubes. To these yokes are bolted the sides and bottom—sheet iron plates—thus forming a hollowed square enclosure. Each hole is furnished with a lifting door large

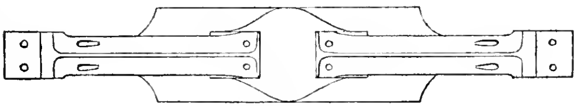
NEW CONDUIT OF THE PHILADELPHIA TRACTION COMPANY.



Elevation.

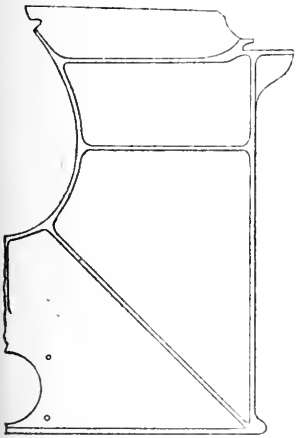


End View.

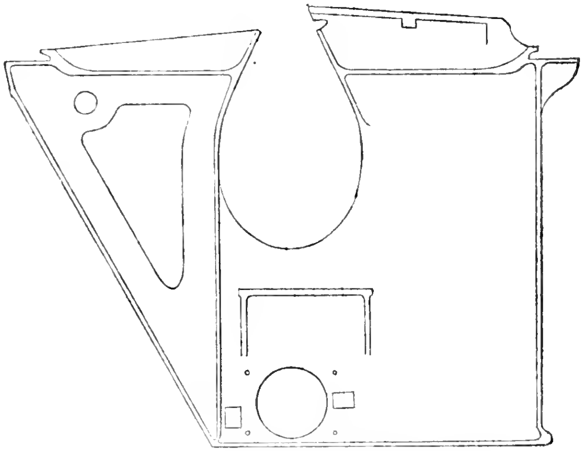


Plan.

(*Scale, 2 feet = 1 inch.*)

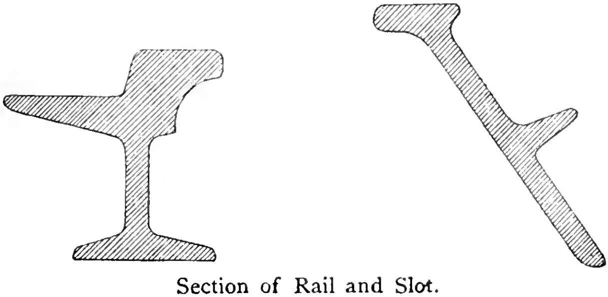


Elevation of Man-Hole.
(Outside View.)



Elevation of Man-Hole.
(Inside View.)

(*Scale, 2 feet = 1 inch.*)



Section of Rail and Slot.

(*Scale, One-fourth.*)

enough to allow the passage of one man. The man-holes are easily accessible and of ample size, and repairs and attendance to the pulleys, etc., may be made with great ease. The new system provides for complete drainage of the conduit, and as all parts of the conduit requiring attention are easy of access through the man-holes, there is little inconvenience in maintaining the cable in proper running order.

Running the entire length of the line, and below the conduit, is a nine-inch terra-cotta pipe for drainage. This pipe connects with the sewer at the foot of the grades. The man-holes empty into the pipe, and its mouth is protected from the entrance of large obstructions by means of a grating door. The pipe enters the man-hole just above its bottom.

The force of men employed at present in laying this new plant on Seventh Street is about 250. Each man works ten hours per day, and the lowest pay per day of a laborer is $1.50. The cost of laying the conduit complete, exclusive of the after-paving of the street, is about $2.50 per lineal foot, and the progress made on the work amounts to about 400 feet per day.

The new system differs from the old principally in that the supports for the conduit are single pieces, and form of themselves a single truss, fully capable of resisting any lateral or other pressure tending to change the gauge and to compress the slot. The width of the slot and the gauge of track are maintained constant by this yoke. All repairing may be done without disturbing any but the part in need of repair.

THE IMPORTANCE OF TUNNELS AND CROSS-CUTS IN ANTHRACITE MINING.

BY HENRY A. WASMUTH, M.E.

The southern and middle anthracite coal fields consist of a number of synclinals with flexures or flanks of an average incline of more than 30°. The number of workable coal beds in those synclinals differ, locally, partly on account of their natural deposition and partly on account of erosion, etc., after their origination.

Naturally, the coal beds of six feet and more thick have been selected for exhaustion, principally the Mammoth bed in the southern and middle coal fields, until now about fifty per cent. of the shipments are mined from other beds of the series in the western middle coal field. Large shipments have also been mined from the Lykens coal beds in the western portion of the southern coal field.

It is an irrefragible principle of mining, that those methods of mining are the most to be recommended by which, without disadvantage to future developments, the earliest and greatest returns may be secured. The application of this mining principle is facilitated by the topography of the greatest portion of the anthracite field. The facilities are:

(1) Exposure of the outcrops of numerous coal beds.

(2) Elevation of some outcrops of coal beds to about 800 feet above natural water levels.

The first facility favors the opening of mines on the coal beds by slopes, and the second, mining above water level or natural drainage. The opening of mines by slopes is the predominant practice in the middle and southern coal field; but, the advantage of "tunnelling" at water level has not been appreciated to its value. It is true, that since steam has been employed for drainage, etc., the apparent value of natural drainage has decreased, but in a formation like the southern anthracite field, the crossing of the strata is indispensable for the knowledge of stratification, and where this has been neglected almost entirely by greed for quick returns, in many instances it has been to the disadvantage of

further developments, to be remedied at great expense in the nearest future. In order to prove this, I refer to the principal systems of opening mines in Europe. Where the topography is favorable and paying lifts are in prospect, mining has been carried on by adits on the deposits and across the formation. It is well known, that the carboniferous formation, to a large extent, is overlaid by younger formations in England, and to keep the surface and marl water from the comparatively dry, gently dipping and most regularly deposited coal beds, shafts with cast-iron lining were sunk as early as 1795 to the first workable coal bed, and when this was exhausted, to the next one, etc. It is obvious that the crossing of such strata would be very uneconomical. Similar developments have been adopted for the moderately inclined coal beds in Westphalia; but, where the coal beds dip more steeply, the shafts have been sunk at once for one or two lifts and the strata crossed; also, in France, Belgium, etc. Slopes are rare exceptions now, though cheap at first, they are expensive in the long run, for the output to a certain degree is limited, and wear and tear of hoisting and pumping is greater than by shafts. Whether a mine is opened by a slope or a shaft, the crossing of steep dipping strata in the upper levels secures the knowledge of the geometrical position of the coal beds, and to a certain degree the existence of faulting, and without such knowledge the developments lack the necessary basis.

From this brief review, it will be seen that mining in this country is a repetition of European methods. In the nearly flat anthracite beds of the Wyoming region and the gently dipping bituminous coal beds of Western Pennsylvania, no system will answer so well as the English system; while in the greater portion of the middle and southern coal field, where a series of workable coal beds have been compressed into narrow synclinals and minor rolls, with steep inclined flanks, the German system will prove to be most adaptable, applied already in Middle Creek Colliery, etc. To ascertain the condition of coal beds not yet crossed in this colliery, would require either the continuation of the cross-cut in both directions at the bottom of the shaft, or holes with the diamond drill, but I would not advise the latter, for the question is not to prove the existence of coal beds, but to prove the workable condition of coal beds known to overly the Primrose bed, and also the known series of

beds towards the bottom of the formation, which would be effected by the diamond drill with problematical results. Such a crossing of the strata would give at least three lifts for the beds overlying the Primrose, and at least six levels on the Lykens beds (of course, if in workable condition). To lower such vast amounts of coal from five lifts to shaft level would be very expensive, and a calculation would prove the advantage of first driving an adit to the Lykens series.

The numerous adits in the Panther Creek region are similar to the old and numerous long adits in the southern portion of the coal field in Westphalia. In both regions, the geometrical position of the coal beds has been indicated by those adits, but while the strata are dislocated by faults of both characters in Westphalia, longitudinal faulting is predominant in the Panther Creek region.

The celebrated West Brookside Colliery has been developed to about the elevation of tide level by slopes, and further developments will be necessary in the nearest future. Except a few cross-cuts to the little Lykens and White seams, and a line of shaftings across Bear Valley, about two miles east of Slope No. 4, there is no further information of the geometrical position of the north-dipping coal beds in this colliery, and as the great disturbance of the strata in Williamstown Tunnel certainly will be struck in Brookside also, thus greatly interfering with the little knowledge of stratification of that district, there are no other means to ascertain the geometrical position and workable condition of certainly existing coal beds than either by tunnelling at water level, or sinking shafts and from these crossing the strata. The diamond drill would be of little value in broken and confusedly dislocated strata, known to be at least 1,500 feet long horizontally and no indication where the disturbance will either die out or leave the coal measures to the east. The truth of this will be shown very soon by the new shaft of Williamstown Colliery, in Bear Valley.

From Williamstown Tunnel to Branchdale there are several great disturbances of the strata not represented by any map:

(1) The disturbance in Williamstown Tunnel already referred to, by which most probably the Bear Valley basin and its whole south-dipping flank has been dislocated towards the north, is similar to the dislocation of considerable strata north, exposed in Rhume Run Tunnel No. 1.

(2) The disturbance (most probably by longitudinal faulting) north of Good Spring railroad station.

(3) The disturbance east of Colket Colliery, developed in this and Middle Creek Colliery and the longitudinal fault developed in the latter.

(4) The disturbance of the strata developed by shafting, and, if I remember correctly, also in tunnelling in Swatara Colliery.

(5) The longitudinal dislocation of the whole strata developed in all levels of White Ash slope in Otto Colliery, and most probably another great disturbance in the neighborhood of School Row.

To meet the difficulties of those disturbances in further developments, will require:

(1) The abandonment of the notion of existing inversions in coal beds.

(2) The crossing of the strata, either between two such disturbances, or, for the discovery of the dislocated coal beds, according to the rules.

It is a well-known fact, that in the region referred to, the flexures of the Primrose, Mammoth and Lykens Valley beds in good condition have been mined extensively, and the remaining workable coal beds of the series, not touched yet, will have to be developed very soon by shafts and crossings of the strata, provided that no new system should be devised to accomplish the object more economically.

4128 Elm Avenue, Philadelphia, December, 1887.

A REVIEW OF PROGRESS IN THE ARTS AND MANUFACTURES IN 1887.

[*From the Report of the Secretary to the Annual Meeting of the* FRANKLIN INSTITUTE, *held Monday, January 18, 1888.*]

IN RESPECT to general commercial and industrial activity, the year that has just passed into history has been the most prosperous that the United States has ever known. The hopeful signs of industrial revival, which were visible toward the close of 1885, and which were fully established throughout the year 1886, appear to have reached their culminating point in 1887, in which industrial operations were expanded to hitherto unequalled proportions. As is invariably the case, in the recurring periods of prosperity, with which we have become so familiar, the favoring conditions exhibit themselves most clearly in the various branches of the iron trade. The year 1886, as I had occasion to note in my summary of progress for that year, was characterized at its close as the most prosperous year ever known in the history of the iron industries in the United States, in which, likewise, production in all branches exceeded that of any previous years. The year 1887 was a no less prosperous one for the iron trade and was one of even greater activity. I have the high authority of Mr. James M. Swank, of the American Iron and Steel Association, for the following data respecting the *American iron trade* for 1887, which are abstracted from his annual review. From this it appears that production in all leading branches of the manufacture of iron and steel was the largest in our history—larger than in the remarkable year 1886, when all previous achievements were left far behind. He estimates our production of pig iron in 1887 at 6,417,148 gross tons, or about 800,000 tons more than in 1886, when our production was 5,683,329 tons. Our production of Bessemer steel rails in 1887 was about 1,950,000 gross tons, or about 375,000 tons more than in 1886, when our production was 1,574,703 tons. In addition to our large production of pig iron in 1887 we also consumed about 500,000 tons of imported pig iron, and about 160,000 tons of imported steel rails. Our imports of iron and steel in other forms in 1887 were also very large, the total importations of iron and steel in all forms aggregating nearly 1,800,000 tons. Our production of iron ore in 1887 was about 11,000,000 gross tons, and our imports in the same year amounted to about 1,250,000 tons. In 1886 we produced about 10,000,000 gross tons of iron ore, and imported 1,039,433 tons. In November, 1887, there were in the United States 582 blast furnaces, entitled to be classed as active, the annual capacity of which Mr. Swank estimates at about 11,000,000 tons. Particularly noteworthy is the great activity in the construction of new furnaces during the past year, especially in the Southern States, Tennessee and Alabama, where the development of the iron industries during the past two years has been exceptionally

rapid. Mr. Swank tells us that at the close of November, 1887, there were thirty furnaces under construction, of which no less than nineteen, or nearly two-thirds, were located in Alabama.

The number of rolling mills on the active list in November, 1887, is placed by Mr. Swank at 433, with twelve building, and their annual capacity in finished iron and steel is estimated at 8,265,000 tons. Of special interest are the figures exhibiting the growing application of natural gas for fuel by iron and steel manufacturers. In September, 1884, natural gas was in use in six establishments; in August, 1886, sixty-eight rolling mills and steel works were using this fuel; in November, 1887, this number had risen to ninety-six. (No allusion is made at this point to the use of natural gas as fuel in other manufacturing operations, notably for glass making, in the regions adjacent to the oil-producing territory, in which it has very generally superseded the employment of solid fuel.)

In November, 1887, there were in this country, thirty-five standard Bessemer steel works, with seventy-four converters, and three new plants were in course of erection. The annual ingot capacity of these works (including that of the works now building) is placed by Mr. Swank at 4,750,000 tons.

Of the Clapp-Griffith steel industry, of which great things were predicted a few years ago, Mr. Swank remarks that it has not exhibited much progress since 1886. The first works using the Clapp-Griffith process was erected in this country in 1884; in 1886 the number had grown to six, with two in construction, containing thirteen converters in all; while in November, 1887, there were eight completed works, and one in construction, having in all sixteen converters, and having an annual ingot capacity of 225,000 tons. The open-hearth industry, from Mr. Swank's data, exhibited great progress during the past year. In August, 1886, there were forty-two completed open-hearth steel works in the United States and seven in course of erection. In November, 1887, there were fifty completed works and three in course of erection. The open-hearth steel works in 1886, completed and building, contained eighty-nine furnaces, and, in 1887, they contained 104 furnaces. In 1886, the annual ingot capacity of the works completed and then building was 660,000 tons, and in 1887, it was 815,000 tons. The crucible steel works increased from forty in 1886, to forty-one in 1887, with 3,398 pots.

There was a falling off in the demand for nearly all forms of iron products, which became more and more decided towards the close of the year.

During the year 1887, there were added to the railway systems of the United States, according to the estimates of the *Railway Age*, 12,724 miles of new track. These figures represent main line only, and are exclusive of the large amount added in the form of the side tracks and for renewals. The railway construction in 1887 is the largest ever attained in a single year before, exceeding the figures of the year 1882, in which 11,568 miles were built, and which, it has been repeatedly predicted, would never be surpassed. It may, however, be safely asserted that the year 1888 will witness a decided curtailment of new railway constructions; for it is generally believed that a large proportion of the phenomenal construction of 1887 was built principally for the purpose of occupying, in advance of rivals, at present unproductive, but

prospectively valuable territory. The number of miles of railway in the country at the close of 1887, is placed by the authority above quoted at 150,710 miles.

The domestic *production of coal* in 1887 also reached higher figures than in any previous year. The *Engineering and Mining Journal* estimates the output to have been about 110,000,000 tons, of which 36,626,627 tons were anthracite, and 74,000,000 tons bituminous. Of the last, about 8,000,000 tons were converted into coke. These figures show an increase of about 10,000,000 tons over those of 1886. On the authority of the journal above named, it may prove useful to add the figures of production of the principal metals employed in the industries, all of which exhibit advances over all previous years, to wit: the domestic production of lead, in 1887, was 160,000 tons, as against 143,957 tons, in 1883, which was the largest output previously recorded; of copper, 81,473 tons, in 1887, as against 76,000 tons in 1885; and of zinc, 51,000 tons, as compared with 38,072 tons in 1886.

The aggregate gold product of the United States in 1887, is placed by Mr. John J. Valentine, at \$32,500,067, against \$29,561,424 in 1886, and is the largest of any year since 1880, when \$32,559,067 was produced. The total silver product is given at \$50,833,844, which with the exception of the \$52,136,851 produced in 1886, is the largest ever known.

IN ENGINEERING, the most prominent subject of discussion was the Panama Canal. Respecting this work, the events of the past year have only served to confirm the belief that has long been entertained among those best qualified to judge, that it was undertaken with an utterly inadequate understanding of the difficulties to be encountered, and that it has been continued with a reckless disregard of consequences, that has no parallel in the history of modern engineering enterprises. The latest reliable information respecting the condition of the work is contained in the official report of Señor Armero, the agent of the Colombian Government, the results of whose investigations of the company's affairs and the state of the engineering operations on September 1st, makes a truly alarming exhibit. He states, in brief, that the total amount of excavations required, according to the company's plans, is 161,000,000 cubic metres, of which up to September 1st, 33,925,230 had been taken out, that the company had expended up to that time, the sum of 818,032,900 francs (considerably more than the original estimated cost of the entire work), and that the most difficult portions of the work have scarcely been commenced. He estimates that to finish the canal, on the original plans of the company, will require an additional expenditure of over 2,000,000,000 francs. The latest utterances of the head of this enterprise, are to the effect that, having in mind the pledges repeatedly made, to have the canal open to traffic in 1890, the plan of a "sea-level canal" will be temporarily abandoned, and a system of locks adopted instead.

At the famous International Congress, in Paris, at which the Panama scheme was enthusiastically agreed on, it was vehemently insisted by De Lesseps and his following, that to fulfil the requirements of international commercial intercourse, a *canal à niveau* was imperatively necessary. Comment thereon is unnecessary.

The fact is worthy of note at this point, that an American Company that has secured a concession for the construction of a canal across Nicaragua, took the first steps near the close of the past year towards putting their plans in operation, by sending out an engineering corps to commence work.

Work upon the great Forth bridge during the past year has been steadily advanced. This will have a total length, when completed, of 8,300 feet. It will have two main spans of 1,700 feet each, and two side spans of 675 feet each. There will be 150 feet of clear way between water level and the central 500 feet.

In this country, the year 1887 witnessed the commencement of work on the much-needed bridge over the Hudson River, at Poughkeepsie, respecting which Mr. Grimshaw furnishes us with the following details: It will have a total length of 6,667 feet, the bridge proper being 3,093 feet. There is from 130 to 160 feet head room, and the structure is entirely of steel, even to the rivets. It will make an almost direct route from Boston and Springfield to Scranton, the anthracite coal fields and Harrisburg. There are four piers in the river; these are of masonry resting on timber caissons dredged down 140 feet below high water. The substitution of steel towers for masonry greatly diminishes the pressure on the foundations, and the substitution of three cantilever spans of 540 feet each, and two connection spans of 525 feet each, for five disconnected spans of 525 feet each, enables the erection of the three cantilever spans without staging in the river, and gives more water way between the piers and a clear height of 160 feet instead of 130 in three of the spans. An important bridge of stone and steel is being constructed over the Harlem River, at One-Hundred-and-Eighty-first Street, New York, which, when completed, will have a length of 2,375 feet, and a height of 151 feet above the water. A bridge across the Missouri, near Kansas City, was nearly completed during the past year. It has three spans of 400 feet each, one of 250, one of 200, two of 175 feet each, and a viaduct of about 2,000 feet in length. It is intended for the Chicago extension of the Atchison, Topeka and Santa Fé Railroad. A fine railway bridge of nine spans across the same river, at Rulo, was built during the year for the Chicago, Burlington and Quincy Railroad.

Work upon the Croton Aqueduct was vigorously pushed forward during the past year, and its early completion may be anticipated. When the improvements to be made in connection with it are completed, it will be competent to supply the city of New York with 200,000,000 gallons of water per day.

An important engineering work, which was undertaken during the past year, is the Holstein Canal, which, when finished, will join the North Sea with the Baltic, and will be of material service to commerce. Certain projected engineering works are worthy of a word of allusion in passing. The

Simplon Tunnel, which has long been talked of, was the subject of some discussion. A proposal has been seriously made to build a submarine tunnel to join Prince Edward's Island with the mainland. The length of the tunnel would be eight miles. The much-talked-of project of tunnelling the English Channel appears, for the present at least, to have been dropped, and for the most extraordinary of reasons—namely, the fear on the part of the English military authorities that it might be captured by their Gallic neighbors, and used as an avenue for the invasion of English territory. Extensive improvements of the Queensland harbors and rivers have been decided upon, and similar improvements are contemplated for the ports of Lisbon and St. Petersburg. In this country, the so-called Hennepin Canal, to unite the waters of the Great Lakes with the Mississippi, has been vigorously advocated; the improvement of the navigation of the Delaware River at Philadelphia has also been discussed, and the project of a ship canal across New Jersey from the Delaware River to the ocean has been revived in the interests of our coastwise traffic.

The projected Manchester ship canal begins at Eastham, on the south bank of the estuary of the Mersey, following its bank thirteen and one-half miles, then almost direct to its terminus in the docks at Salford and Manchester. Locks, docks and sluices will have to be made, railways diverted and carried overhead, roads carried over, drainage and water supplies carried under, ferry approaches made and traffic provided for, jetties and wharves built, miles of new roads and streets made, and along portions of the route walls and fences built equal almost to fortifications. The total length will be over thirty-five miles.

In foreign countries there has been unusual activity in railway construction. Russia is engaged in the extension of a great system of railways in Siberia and her other Asiatic possessions; England is doing the same in India; and Japan added considerably to her railway mileage during the year. In the United States, the Strong locomotive was the subject of much comment. Noteworthy are the exhaustive experiments made by the Pennsylvania Railroad Company with the Urquhart system of burning petroleum as fuel on locomotives, which is in successful operation in Russia. The results obtained appear to be quite satisfactory, but the use of this form of fuel for locomotives has been demonstrated to be impracticable on the score of expense.

The action of the Legislatures of several of the states forbidding the use of stoves in railway cars, called forth many suggestions, and several systems of heating with steam have been experimented with, and with promising results. Of interest in this connection, also, are the successful trials of last year, of a system of continuous brakes for freight train service, devised by Mr. Westinghouse.

Some suggestive operations and propositions in connection with the economical distribution of power, are worthy of notice in recording the progress of the past year. We learn, for example, from Mr. Grimshaw's comments on this subject, that "The Birmingham experiment of supplying power by compressed air is now in successful operation on a small scale. The project of utilizing the waste power of Niagara has been revived, at

least to the extent of intending to transmit 200,000 horse-power through a tunnel having a maximum diameter of thirty feet and discharging 861,000 cubic feet per minute. The maximum head is 124 feet at Port Day. The contract has been awarded. The Stafford prize of $100,000 for a contrivance to convert the flow of the water of Niagara River into practical power, has not yet been awarded. The Hydraulic Power Company has, in London, about twenty-five miles of mains constantly charged with water at a pressure of 700 pounds per square inch. Service is continued without intermission day and night, Sundays and week-days. In many cases, existing pumping machinery has been discarded in favor of the Power Company's water, and lifts and cranes have been modified to render them suitable to its use." And from the same authority I glean that "the past year has been very productive of fast boats. The *New York*, designed for North River service, 311 feet long and 12 feet 3 inches in moulded depth, accomplishes twenty-three miles per hour. The *Now Then*, 85 x 10 x 3¼, has averaged twenty-four miles per hour for 170 miles—the fastest time for a steam vessel for any considerable distance on this side of the Atlantic. The *Queen Victoria*, of the Manks line, is 340 x 39 x 24, gross tonnage of 1,500 tons, engines 6,000 horse-power; steamed 240 miles at an average of 25·62 miles. Thorneycroft & Co. have produced a boat 147½ feet long, making thirty miles an hour. The Thompsons, of the Clyde, are building steamers to surpass the *Etruria* in speed. The Italian iron-clad *Dogali*, 267 x 37 x 14½ feet, has a speed of twenty-three miles; the German war steamer *Greif*, 25⅓. The Thorneycroft torpedo boat for Spain, 147½ x 14½ x 4⅔, has made thirty-three and one-half per hour with tide, and a mean of thirty per hour with and against tide. The Yarrows have built twin-screw torpedo boats for the Italian Government, attaining a mean speed, loaded, of twenty-eight miles. The *Umbria* has run from Queenstown to Fire Island in six days two hours and thirty-seven minutes, the fastest time on record. The Atlantic liners are developing in speed. The ocean transit is made at the average rate of speed of 16·1 knots for the North German Lloyd, 14·8 for the Cunard, 16·8 for the Compagnie Transatlantique, and 14·1 for the White Star and for the Guion. The time of mail transit from Adelaide has been reduced to twenty-seven days five hours, actual time, via Brindisi and the Suez Canal. This includes twelve hours' delay at Suez waiting for the train to Alexandria."

In the Field of Electricity, there has been substantial improvement in many directions. In respect to the methods of generating electric currents, Mr. Edison's suggestion to obtain electricity directly from fuel without the intervention of the steam engine, is worthy of special notice.

Realizing that there was but faint hope of success in improving upon the thermo-pile, which, in its best forms—which are the product of innumerable experiments—yield an extremely low efficiency, Edison has attempted to take advantage of another principle, namely, the varying magnetic capacity of iron at different temperatures. His statement, which covers the essential feature of his invention, is as follows:

"It has long been known that the magnetism of the magnetic metals, and especially of iron, cobalt and nickel, is markedly affected by heat. According to Becquerel, nickel loses its power of being magnetized at 400°, iron at a cherry-red heat, and cobalt at a white heat. Since, whenever a magnetic field varies in strength in the vicinity of a conductor a current is generated in that conductor, it occurred to me that by placing an iron core in a magnetic circuit, and by varying the magnetizability of that core by varying the temperature, it would be possible to generate a current in a coil of wire surrounding this core. This idea constituted the essential feature of the new generator, which, therefore, I have called a pyro-magnetic generator of electricity."

Mr. Edison has constructed such a generator on this principle, and states, respecting its efficiency, "the results thus far obtained lead to the conclusion that the economy of production of electric energy from fuel by the pyro-magnetic dynamo, will at least be equal to, and probably greater, than that of any of the methods in present use." Mr. Edison has also applied the same principle to the construction of a pyro-magnetic motor. It may be of interest at this point to record the fact that the underlying principle of the pyro-magnetic generator was embraced in the thermo-magnetic motor of Houston and Thomson, which was first described in the JOURNAL of the INSTITUTE, for January, 1879.

The efficiency of the *dynamo-electric machine* is so high, that there would appear to be small encouragement for inventors to seek to improve upon it; nevertheless, numerous improvements, though of minor importance, have been proposed, with the view of increasing the duty of the dynamo per pound of material.

The most noteworthy suggestion in relation to the *primary battery*, is that of Mr. Willard E. Case, who has devised a form of cell in which carbon —which in all forms of primary battery hitherto used, has played the part of the negative or unalterable element—forms the positive element of the couple, the other element being platinum. The electrolyte is sulphuric acid to which potassium chlorate is added. The chemical changes taking place in the electrolyte involve the liberation of oxides of chlorine, which attack the carbon. Mr. Wetzler in this relation, calls attention to a new class of voltaic combinations, in which the oxidizable metals are replaced by alterable solutions. In these, solutions are oxidized, and act as electrodes, instead of the oxidizable metals, such as zinc.

The *secondary battery* has received its full share of attention during the past year, but the improvements that have been suggested, relate to details, and no radical improvement is to be noted.

Of the *electric motor* no very pronounced improvements are to be recorded. Their application to city railways, however, attracted an unusual amount of interest during the year. In connection with this subject, the extended trials of the method of employing secondary batteries carried upon the car, to actuate the electric motor, have been made in New York, Philadelphia and other cities, and with satisfactory results. The mode of gearing the motor to the axles of the car is now recognized as an element of the greatest importance, and the relative merits of steel spiral cords, chain gearing, conical discs and

chains, straps and pulleys, spur gearing, friction gear and worm gearing, were warmly discussed. Several ingenious methods for avoiding the use of a slotted conduit in connection with electric railways, employing continuous conductors, were proposed during the year.

In evidence of the rapid introduction of the *electric railway*, the following enumeration of the cities and towns in which it is in use, and which I give on the authority of Mr. T. C. Martin, will be of interest. The cities and towns in which the electric railway is actually in operation, are: Appleton, Wis.—Appleton Electric Street Railway; overhead conductor, four and one-half miles, five motor cars; Van Depoele system. Baltimore, Md.—Union Passenger Railway Company; overhead conductor; Daft system. Denver, Col.—Denver Tramway Company; conduit, four miles; Short-Nesmith series system. Binghamton, N. Y.—Washington Street and State Asylum Electric Railroad; overhead conductor, five and one-half miles; Van Depoele system. Detroit, Mich.—Detroit Electric Railway Company; overhead conductor, two miles, four motor cars; Van Depoele system. Highland Park Railway Company; overhead conductors, three miles, two motor cars. Gratiot, Mich.—Gratiot Electric Railway Company; overhead conductor, one motor car; Van Depoele system. Kansas City, Mo.—Kansas City Electric Railway Company; Henry system. Lima, O.—Lima Street Railway Motor and Power Company; overhead conductor, six and one-half miles, seven motor cars; Van Depoele system. Los Angeles, Cal.—Los Angeles Electric Railway Company; overhead conductor, five miles, four motor cars; Daft system. Montgomery, Ala.—Capital City Electric Street Railway Company; overhead conductors, eleven miles, twenty motor cars; Van Depoele system. Port Huron, Mich.—Port Huron Electric Railway Company; overhead conductors, two and three-quarter miles, three motor cars; Van Depoele system. Scranton, Pa.—Scranton Suburban Railway Company; overhead conductor, two and one-quarter miles, three motor cars; Van Depoele system. Windsor, Can.—Windsor and Walkerville Electric Railway Company; overhead conductor, one and one-half miles, one motor car; Van Depoele system. In the following places lines are being constructed, or under contract: Ansonia, Conn.; Asbury Park, N. J.; Allegheny, Pa.; Dayton, O.; Harrisburg, Pa.; Lakeside, O.; Los Angeles, Cal.; Middletown, Conn.; Mansfield, O.; New York, N. Y.; Pittsburgh, Pa.; Richmond, Va.; San Diego, Cal.; St. Catherines, Can.; St. Joseph, Mo.; Worcester, Mass.; Woonsocket, R. I.; Wilmington, Del.; Wichita, Kan.

In *electric lighting*, the most noteworthy feature of the past year has been the successful introduction of systems of electrical distribution by alternating currents and transformers, of which that known as the Westinghouse system has been the most prominent. The continued growth of electric lighting, both by arc and incandescence, especially the last named, is noteworthy. Of interest is a system of railway car lighting, suggested by Mr. Barrett, which involves the use of both dynamo and storage battery, the latter intended to be charged by the surplus current of the dynamo, and to be called automatically into requisition when any of the cars are detached from the train.

In *telegraphy*, beyond general improvement in existing methods, there is nothing of importance to note.

In *telephony*, the considerable extension of the long-distance lines during the past year is worthy of special notice. The first of the long-distance lines to be opened for traffic was that between New York and Philadelphia, which was put in operation about the beginning of the year. The advices are to the effect that there were at the close of the past year fifty wires, constituting twenty-five circuits, at work between New York and Philadelphia. Of these, some are leased outright to business men and companies; others are divided among a number of business firms, and a number are retained and are operated from public stations for the transmission of miscellaneous business. In New York, I am informed, there are now 130 offices in which there is direct communication with Philadelphia, independent of the metropolitan telephone service, and in Philadelphia there are forty offices in like manner independent of the local city service. During the year, the lines of the American Telephone and Telegraph Company, which is engaged in the long-distance telephone business, have been considerably extended throughout the Eastern States, and from the latest information at my command, it appears that the lines of the company now run through Stamford, Norwalk, Bridgeport, Birmingham, Ansonia, New Haven, Meriden, New Britain, Hartford, Essex and New London, and connection is made with all points on the line of the Southern New England Telephone Company in Connecticut. Before the winter is over, the company expects to have its lines open to Worcester and Boston. Lines to Albany, N. Y., will be finished before winter, and to Washington before spring.

Considerable improvements have been made in apparatus and methods for recording and reproducing speech. Mr. Wetzler, in a report of electrical progress for the year just passed, refers to certain electrical methods devised for this purpose; one, devised by Mr. Irish, and termed an electro-thermal recording telephone, and the other a repeating phonograph, devised by Mr. Hunter; both of them are spoken of in favorable terms.

The substantial improvements that Mr. Edison is thought to have made in his well-known phonograph were widely published and commented upon. Although this apparatus is not electrical, I take the liberty of referring to it here as perhaps the most convenient place. In his new apparatus, Mr. Edison dispenses with the tin foil, and receives the phonograph record upon a hard and smooth cylinder of wax. Other details relate to improvements in mechanical construction, and the employment of an electric motor to obtain more perfect uniformity of rotation. In this field, Mr. Berliner's invention of an instrument, that he terms the "gramophone," is especially worthy of notice. Mr. Berliner receives the impression of the sound waves upon a lamp-blacked surface of plate glass, on which the stylus traces the record in a direction parallel to the surface of the plate, instead of at right angles to the receiving surface, and which offers, therefore, practically no resistance to the movements of the tracing point, as must be the case where tin foil or wax is indented by the tracing point. The phonogram sheet thus obtained—in this case a spiral line exhibiting, on close inspection, innumerable minute

serrations—is used as a photographic negative, from which, by the process of photo-engraving, electrotypes in copper are obtained. This is the permanent record, and by using these upon the reproducing apparatus, the plate, actuated by proper means, will guide the stylus through the intricacies of the spiral line, and, setting up the corresponding vibrations in the diaphragm, cause the spoken words to be repeated. These improvements in the phonograph seem to be very pronounced, and it is not improbable that the phonograph may shortly take a place as important in our every-day business life as the type-writer or the telephone.

DURING the past year, there has been a considerable extension of the *natural gas* territory, and in the states of Ohio and Indiana the discoveries that have been made are considered to be of the first importance to the industrial development of the regions affected thereby. Throughout Western Pennsylvania the multiplication of manufacturing establishments, attracted by the advantages offered by the new fuel, has gone on uninterruptedly, and the changes which it has wrought within the past few years are little short of the marvellous. The appliances for using the gas as fuel for manufacturing and domestic purposes have also been notably improved, and it is now under such complete control and regulation that objections to its employment on the score of danger may be regarded as substantially removed.

IN CHEMICAL TECHNOLOGY, it is a matter of interest to record the successful demonstration, in England, of the utility of the Castner process for producing the *alkali metals*, which was named as a promising innovation in my review of one year ago. Careful trials of the new process, with an experimental plant on a considerable scale, appear substantially to have established the claims of the inventor. The experimental furnace was capable of treating 720 pounds of caustic soda daily, giving a yield, in twenty-four hours, of 120 pounds of sodium. The estimated cost of production, taken from the actual running of the furnace, is eight and one-fourth pence per pound. The manufacture of sodium on the large scale, by this procedure, it is confidently anticipated, will effect the decided cheapening of many chemical and metallurgical products.

The cheap production of the *aluminium* bronzes in the electric-smelting furnace of the Cowles' Brothers, has attracted the attention of military engineers to the suitability of this metal for the manufacture of heavy ordnance. No further advance during the year in the production of aluminium in the Cowles furnace is to be noted; but I am advised that this metal has been made in considerable quantities in Berlin, by the electrolysis of aluminium salts kept in a state of igneous fusion. This process, it is said, has substantially lowered the market price of the metal.

It is worthy of note that during the past year more attention than ever before has been devoted to the *domestic production of sugar* from the beet and

from sorghum. The beet sugar industry has firmly established itself in California, and extensive enlargements of the existing plant in that state are about being made, which will largely increase the production. Important improvements have likewise been made during the past year in the processes for extracting sugar from the sorghum plant, which, it is believed, have overcome the difficulties that have hitherto stood in the way of the profitable production of sugar from this source.

In *photography*, several ingenious suggestions for obtaining an instantaneous or flash light of highly actinic quality for photographic uses, attracted attention. The basis of this light is magnesium in the form of powder, which is deflagrated with the aid of some suitable substance. For this purpose, the proposed method of Dr. Piffard is perhaps the best. He uses preferably a tuft of photographer's gun-cotton upon which the magnesium powder is sprinkled.

In *illumination* (other than electric), the Welsbach incandescent light, brought out during the past year, may be named as the principal item of interest. It is adapted to be used with any non-luminous gas, either water gas or ordinary coal gas rendered non-luminous by admission of air into the burner. It is made by immersing a fine woven fabric of cotton, of proper shape, into a solution containing salts of zirconium, lanthanum, etc., and subsequently burning out the cotton fibre. The resulting product is the mineralized skeleton of the fabric. It affords, when suspended in the flame, a brilliant and perfectly steady light, claimed to yield from two to three times the amount of light yielded by coal gas burned in the usual way, and to be sufficiently durable in service for all practical purposes.

Of miscellaneous inventions of interest, mention should be made of two which were given their first publicity at the meetings of this INSTITUTE, and which give high promise of utility. I refer to Thomas Shaw's invention of an automatic signaling system, for detecting the presence of explosive gases in mines, and preventing loss of life and damage to property; and Mr. Alexander E. Outerbridge's very ingenious process for casting iron and other metals upon lace, embroideries, and the like.

Without entering upon the domain of pure science, which would carry me far beyond the bounds I have assigned to this review, I cannot refrain from mentioning in conclusion a few notable events which the past year has brought out. It is proposed to make the wave length of sodium light the actual and practical standard of length. Stroumbo has devised an ingenious method of recomposing white light from the spectrum colors, and has improved on Sir Isaac Newton's celebrated experiment with a revolving parti-colored disc, utilizing the persistent colors of the spectrum. The spectrum is projected on a white screen, and the prism rotated rapidly until the space swept by the spectrum on the screen is seen as a band of white light. Observations at Lyons seem to confirm the opinion that each period of maximum perturbation of terrestrial magnetism coincides with the passage of a group of solar spots at its shortest distance from the centre of the solar disc.

I may mention, also, that last year the *largest refracting telescope* in the world was completed in Cleveland for the Lick Observatory, Mount Hamilton, Cal. The column supporting the movable parts is of cast iron, 10 x 17 feet at the base, 4 x 8 at the top, and weighs eighteen tons. The steel tube is 4 feet in diameter at the centre and 56½ feet long, tapering at each end to 38 inches. The object lens, made by the Clarks, of Cambridge, Mass., is 36 inches in diameter, and weighs, with its cell, 638 pounds. It is nearly fifty per cent. more powerful than any other yet made. Finally, I may add, that Dr. Wm. Crookes, of London, advanced at the last meeting of the British Association, a most philosophical hypothesis respecting the "Genesis of the Elements," by a species of evolution from an original primal matter, for which he proposes the name of *protyle*.

BOOK NOTICES.

"INDEX OF CURRENT ELECTRICAL LITERATURE."

The American Institute of Electrical Engineers has inaugurated a good work in its publication of the above index. It is the intention to issue this Index with the monthly Transactions. In it will be included the titles of all articles relating to electrical subjects published in electrical and technical journals, and of papers read before various learned societies in this or foreign countries. For ease of reference, these titles will be properly classified.

It is difficult to overestimate the good work that an efficient monthly index of this character can accomplish for the electrical world. Reliable indices in any department of knowledge are always of value to special students. Their value, however, to a great extent, is too frequently diminished by the fact that they are seldom given to the public until the papers or articles they include have lost their novelty, and thus often much of their value.

The above index, however, differs from most in the fact that it is designed to put within ready reach of the electrical world, papers, articles, and discussions showing the present position of the world's progress in electricity. The rapid interchange of thought, and the spread of knowledge as to the directions of greatest activity in matters electrical, cannot, in our opinion, but very considerably excite increased activity.

The first issue of this index covers fourteen printed pages of the Institute's Transactions. The following classes, under which the various articles are indexed, will give some idea of the scope of the work, viz.: Telegraphy; the Telephone; Electric Lighting; Dynamos, Systems of Distribution; Electric Power; Batteries, Electrolysis, Measuring Instruments; Mechanical, and Miscellaneous.

We notice that no attempt at alphabetical arrangement has been made of the topics included under each sub-division. This we think is a mistake. At present, it is true, it makes but little difference, but with the vast number of

titles that such an index must before long include, an alphabetical arrangement will soon become a necessity.

"The index sheets," it is stated "are printed separately, so that they may be detached at once, if necessary. They will all be bound together at the end of each volume of the Transactions."

As the volumes of the Society appear frequently, we would respectfully suggest that each of the sub-divisions of the topics in each volume be printed on a separate sheet; that is, that no more than a single sub-division be placed on a separate sheet or sheets. In this manner it will be possible to rebind the index for any year or number of years, with all the papers belonging to a single topic in one portion of the volume.

We regret to find that the head "Miscellaneous" includes some two and a half pages of titles. This should be avoided; a classification could be adopted to either entirely abolish this head, or greatly to diminish the titles included under it. E. J. H.

NOTES EMBODYING RECENT PRACTICE IN THE SANITARY DRAINAGE OF BUILDINGS. By Wm. Paul Gerhard, C.E. (Van Nostrand's *Science Series*. No. 93.) New York: D. Van Nostrand, 1887.

Mr. Gerhard has here given us a compact manual on the drainage of buildings. We have seldom seen the subject so well handled for daily application. Instructions, precautions, tests and estimates are laid before us in a few small pages. To be more precise, he divides his work as follows: Part I relates to recent progress in house draining; Part II contains maxims; Part III, suggestions for a sanitary code; Part IV, memoranda on the cost of plumbing work. Presumably a handy-book for architects. E.

THE AMERICAN GEOLOGIST. Vol. 1, No. 1. January, 1888.

The first number of this new journal is upon our table.

In its introduction, the need of an exclusively geological journal in the United States is set forth; one "which shall be open to the properly-worded opinions of all, from the most powerful to the most obscure, and which is distinctively committed to no theory." The editors are men of mark in the science, and have the ability to make the journal successful, if the general interest on the part of the cultivators of this science shall be sufficient to sustain their enterprise with the liberal subscription list they deserve.

The first article is devoted to a short history of the origin and acts of the International Congress of Geologists, by Dr. Frazer. Following this are valuable articles by Prof. Winchell and by Dr. Winchell, on the Animike, a formation of great economic importance, including as it does some of the richest, purest and most valuable iron ores of the United States in vast quantity.

Of the other interesting articles, our space forbids mention of more than two. "The Future of Natural Gas," by Prof. Claypole. His views will

probably be upheld by geologists, though very disappointing to the many who think they have in natural gas an unfailing supply of the best and cheapest fuel. Prof. Colvin contributes notes on formations passed through in boring a deep well at Washington, Ia. This well, in a depth of about 1,200 feet, passed through an interesting series of rocks.

In conclusion, it may be said that if the future numbers equal the present one in interest and value, the subscribers will have no reason to complain.

T. D. R.

THE TREATMENT OF SEWAGE. By Dr. C. Meymott Tidy. (Van Nostrand's *Science Series.* No. 94.) New York: D. Van Nostrand, 1887.

Originally this paper appeared in the *Journal of the Society of Arts*, and it has justly been deemed worthy of republication in Van Nostrand's *Science Series.* The author, Dr. Tidy, has been long identified with the sewage question, more particularly as a chemist than as an engineer; yet his work will prove instructive to professional engineers who might wish to arrive at the best opinions held in England regarding the disposal of sewage. The method by precipitation and purification is undoubtedly that which the author considers the most suitable under the conditions prevailing in England. Bearing on this method, he notes certain important details indispensable to its successful application. The method by irrigation does not meet with favor in his eyes. Much information, independent of any process of sewage treatment, is contained besides in the paper. The reader should bear in mind that the conditions of climate, soil, geography and population are very different in England from those on the Continent and in America, and he should realize well these conditions before forming an opinion on the sewage question as viewed by our English cousins. In fact, this precaution has a general application to all engineering problems, but is especially required in studying the treatment of sewage in England. We recommend, in conclusion, this little work to American engineers, who will certainly be called upon to face the difficulties confronting European engineers, when our municipal works shall be regarded as scientific studies instead of political spoils.

E.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

ON THE OXIDATION OF SILVER.—H. Le Chatelier (*Bul. Soc. Chim.* **48**, 342). Since, according to the calculations of Thomson, the oxidation of silver disengages fourteen calories for one molecule of oxygen, the combination should take place directly, as in the case of most other metals. Heretofore this has not been accomplished. According to the laws of chemical equilibrium, the decomposition of silver oxide and the oxidation of the metal must be limited at every temperature by the fixed tension of oxygen. Hydrogen does not combine with oxygen at a temperature below 500°, and the direct oxidation of silver would require a calculated temperature of about 327° with a plus or minus error of 60°. The minimum temperature necessary for the oxidation of silver should be the same as the minimum temperature of decomposition of the oxide, and it is known that the oxide begins to decompose at about 250°. One gramme of pure silver was sealed in a hard glass tube with some potassium permanganate, but separated from it by a plug of glass-wool. Under such conditions, the oxidation takes place distinctly at 300°, as is indicated by the black color of the oxide, while the tension of the oxygen does not exceed fifteen atmospheres. The oxidation cannot be made complete, the largest proportion of oxide formed being five decigrammes for one gramme of silver. W. H. G.

COMPOUNDS OF ORDINARY ALCOHOL WITH WATER.—Mendeleeff (*Jour. Chem. Soc.* **51**, 778) has, by a study of specific gravities of mixtures of alcohol and water, arrived at the conclusion that there are three definite hydrates, containing respectively three and twelve molecules of water to one molecule of alcohol, and three of alcohol to one of water. The first of these has been obtained in the crystalline form at the temperature attained by a mixture of solid carbon dioxide and ether; the second solidifies at —17°. W. H. G.

THE ALCOHOLIC PRODUCTS OF THE FERMENTATION OF GLYCEROL UNDER THE INFLUENCE OF BACILLUS BUTYLICUS.—Charles Morin (*Bul. Soc. Chim.* **48**, 802) has extended the studies of Fitz on the fermentation of glycerol by the bacillus butylicus, and submitted thirty kilogrammes of glycerol to the fermentation in seven operations, each on 150 litres of liquid.

He obtained 3,028 grammes of mixed alcohols, which were separated into the following fractions:

	Grammes.
Ethyl alcohol,	384
Normal propyl alcohol,	482
Normal butyl alcohol,	2,027
Normal amyl alcohol,	131
Residue,	4

The formation of normal amyl alcohol had not been noticed by Fitz. It boils at 137° to 138°, and yields an iodide boiling at 154°. The fermentation of glycerol by bacillus butylicus thus yields a series of normal alcohols, a phenomenon which is characteristic of the microbe. W. H. G.

A NEW APPARATUS FOR FRACTIONAL DISTILLATION IN LABORATORIES. —Edouard Claudon and Charles Morin (*Bul. Soc. Chim.* **48**, 804). This apparatus, for a full description of which we must refer to the original, is constructed of brazed copper, and, according to the liquid to be distilled, is capable of fractionating from four or five to nine litres in an hour as perfectly as a Le Bel and Henninger apparatus of fifteen bulbs. It is provided with tell-tale pressure gauge and regulator, level, emptying stop-cock, froth arrester, sample density gauge, and tell-tale for indicating a full bottle of distillate.

W. H. G.

THE DECOMPOSITION OF HALOGEN HYDRIDES BY OXYGEN IN SUNLIGHT. —Arthur Richardson (*Jour. Chem. Soc.* **51**, 801).—The author finds that "in sunlight the stability of the moist hydrides of chlorine, bromine and iodine is dependent on the mass of oxygen present in excess of that required for their complete decomposition;" the larger the excess of oxygen, the larger the proportion of hydracid decomposed. Even in presence of a large excess of free oxygen, the hydrides of chlorine and bromine are not decomposed when dry or nearly dry. On the contrary, dry hydrogen iodide is decomposed by oxygen under the action of sunlight. W. H. G.

ON THE MIXTURE OF ALDEHYDE AND WATER.—W. H. Perkin (*Jour. Chem. Soc.*, **51**, 816) has studied the density and magnetic rotation of a mixture of aldehyde and water in equi-molecular proportions, and the thermic phenomena at the moment of mixing. If the temperature of the liquids and atmosphere be not higher than 8° or 9°, the temperature first falls and then rises for a long time. In an experiment with twenty-two grammes of aldehyde and nine of water, the temperature at first fell from 7°.46 to 5°.95; it then began to rise, and

After 1 minute was	8°.8
" 2 minutes,	11°.0
" 4 "	14°.7
" 8 "	17° 5
" 12 "	18°.15
" 16 "	18°.4
" 20 "	18°.53
" 24 "	18°.58

It then began to fall very slowly. On attempting to determine the density of the product, the results at first were not concordant, and it was found that when the mixture is subjected to a change of temperature, its volume does not become constant at the new temperature in less than two and one-half or three hours; so that the product must be kept in the density tube during this time before adjusting its volume. The densities are—

$$d\,\frac{0^\circ}{4^\circ} = 0{\cdot}9861 \qquad d\,\frac{6^\circ}{4^\circ} = 0{\cdot}9603 \qquad d\,\frac{13^\circ}{4^\circ} = 0{\cdot}9330.$$

The expansion thus found is greater than that of aldehyde, whereas it should be less were the liquid a mixture of uncombined aldehyde and water, and there is no doubt that the reduction of volume by cooling is owing principally to chemical combination, while the expansion at higher temperatures is chiefly owing to dissociation.

Monohydrated aldehyde does not solidify in a mixture of snow and hydrochloric acid. Its specific magnetic rotation at 15°·7 is 0·8937, the molecular rotation being 3·324; subtracting from this the value of the aldehyde = 2·385, the remainder is 0·928. As this is less than 1, the value of the water, it may be concluded that chemical union has taken place to some extent in the liquid, which therefore contains ethylidene glycol, the proportions varying with the temperature. W. H. G.

PHYSICS.

THE PAILLARD NON-MAGNETIZABLE WATCH.—At the stated meeting of the FRANKLIN INSTITUTE, held Wednesday, January, 18, 1888, Prof. Edwin J. Houston gave, by invitation, an account of some experiments, made by him on the Paillard palladium hair springs and compensating balance wheels for watches. He stated that these experiments convinced him that the palladium alloys employed in the springs and balance wheels examined were destitute of magnetic properties, and that a watch whose balances and hair springs were made of such alloys was not sensibly affected by bringing it near powerful dynamos, nor by subjecting it to extremely powerful magnetic fields.

The Paillard watch examined contains magnetizable material, such, for example, as the steel main spring and steel screws, the springs for the hunting case, etc., etc.

Though magnetism produces no sensible effect on the rate of the watch through the direct magnetic acceleration or retardation of the balance, the question arises whether the movements of the hair spring and balance wheel in the magnetic field might not, like the moving wire in a dynamo, produce a sensible retardation of the watch.

Such retardation might arise in two ways, viz.:

(1) From the permanent field of the watch, due to the magnetization of its magnetizable parts.

(2) From the more powerful extraneous fields into which the watch may be brought.

The first influence does not appear to produce any sensible effect on the rate. The second influence will be experimented on more fully, and a description of the experiments made will be published in a subsequent issue of the JOURNAL of the INSTITUTE. W.

METALLURGY.

THE USE OF STEEL CASTINGS IN LIEU OF STEEL FORGINGS FOR SHIP AND MARINE ENGINE CONSTRUCTION.—In a paper recently prepared by Mr. Wm. Parker, Chief Engineer Surveyor of Lloyd's Register of Shipping, and printed in the *Journal* of the Iron and Steel Institute, some interesting statements are made. It is well known that large forged stern frames and rudder frames are seldom absolutely sound, and that the mortality of wrought-iron crank shafts is excessive.

The superiority of mild steel over iron for the structural parts of ships is now undoubted, and for marine boilers steel has to a very great extent replaced iron. The application, for their approval of the use of cast steel for stems, stern frames, rudders, tillers, quadrants, crank shafts, etc., decided the committee of Lloyd's Register to investigate the physical properties of the material intended to be used, whether the processes used in the manufacture were such as could be expected to secure certainty of results, and to consider what tests would be practicable to determine the quality of the material after the castings have been made.

Tests were made on samples cut from castings, upon the castings themselves, and, for comparison, on forged iron and steel. The results convinced the committee that "structures can be made of cast steel as fit for the purpose intended as those usually made from wrought iron" without the uncertainty associated with the large number of weldings required in making iron forgings.

Inquiries of different manufacturers showed that the methods used, which were the results of their varied experiences, differed widely from each other. Messrs. W. Jessop & Sons melt their steel entirely in crucibles, believing that if it is melted in large masses, as in the Siemens furnace, the metal is not homogeneous enough for structures requiring perfect homogeneity and freedom from molecular strains in every part. Messrs. J. Spencer & Sons use both crucibles and open-hearth furnaces, the size of the casting alone being their guide, while the Steel Company of Scotland use the open-hearth furnace in all this work.

At Messrs. Jessops' the opinion is held that the careful and uniform cooling of the original casting is the only means of ensuring molecular equilibrium, and that (after the casting has become cold) subsequent heating is injurious. All the other steel makers anneal their castings by slowly and uniformly raising the temperature of the casting to that of a bright-red heat, keeping it at that for a length of time and slowly and uniformly cooling it.

Mr. Pourcell, of Terre Noire, attaches importance not only to annealing, but also to tempering castings in oil to increase their ductility. Four specimens, cut from a casting made at Terre Noire were tested. The first, as when cut from the casting, broke at 32·07 tons per square inch, with an elongation of sixteen per cent. in five inches; the second, after annealing, gave 33·7 tons and seventeen per cent.; the third, annealed and tempered in oil, 38·6 tons and seventeen per cent.; the fourth, being twice tempered in oil, gave 41·1 tons, fifteen per cent.

A number of tests of the tensile, bending, percussion and torsional strength of cast steel were made, and the conclusion reached was that while cast steel could be made as reliable as wrought iron, forged steel surpassed in ductility anything that has been yet attained in castings.

As to the quality of cast steel for crank shafts and other engine work, the tensile strength should not exceed thirty tons per square inch, and a piece one and one-fourth inches square should stand bending, cold, through 90°, over a radius not exceeding one and three-fourths inches. H. W. S.

COMPETITIVE TESTS AT WATERTOWN ARSENAL OF BRONZE, AND ALUMINIUM BRONZE AND BRASS.—There have just been completed at the Watertown Arsenal some interesting tests of alloys, which the Government had ordered, with a view to getting the best possible material for the screws for the fifteen or twenty new war ships now building. The results are as follows:

ALUMINIUM BRONZE AND BRASS.

Bronze Composition.	*Pounds Elastic Limit.*	*Per Cent. Elongation.*	*Pounds Tensile Strength Per Square Inch.*
Copper and 8 per cent. Al and Si, . . .	19,000	23·7	58,500
Copper and 10 per cent. Al and Si, . . .	33,000	3·2	68,000
Copper and 8½ per cent. Al and Si, . .	18,000	26·	61,000
Copper and 7½ per cent. Al and Si, . .	19,000	9·3	52,000
Copper and 7 per cent. Al and Si, . . .	17,000	11·9	46,000
Copper and 8¾ per cent. Al and Si, . .	24,000	13·3	66 500
Copper and 9 per cent. Al and Si, . . .	28,000	4·5	66,000
Copper and 10¼ per cent. Al and Si, . .	33,000	3·6	72,500
Brass Composition.			
Copper and 3⅓ Al, 33⅓ per cent. Zn, .	55,000	1·6	70,000
Copper and 3⅓ Al, 33⅓ per cent. Zn, .	65,000	2·5	82,500

GOVERNMENT GUN BRONZE.

	Elastic Limit.	*Per Cent. Elongation.*	*Pounds Tensile Strength Per Square Inch.*
Copper 88, tin 10, zinc 2, per cent., . . .	9,000	1·5	18,000
Copper 88, tin 10, zinc 2, per cent., . . .	10,000	2·	18,000
Copper 88, tin 10, zinc 2, per cent., . . .	13,000	3·	20,000
Copper 88, tin 10, zinc 2, per cent., . . .	11,000	5·	22,500
Copper 88, tin 10, zinc 2, per cent., . . .	13,000	1 5	23,000
Copper 88, tin 10, zinc 2, per cent, . . .	10,000	3·5	19,000

All bars were 22 inches in length by 1⅞ inches in diameter, and 10 inches or 15 inches between elongation marks. The Government gun bronze was made at the Navy Yard, and is the material that has been used universally in both the Army and Navy Departments in the construction of all bronze cannon, propeller wheels, gun carriages, etc., for the past fifty years. The above tests were made at the Watertown U. S. Arsenal, Watertown, Mass., under the auspices of the United States Navy Department, during the week ending December 13, 1887. W.

ENGINEERING.

THE PROPOSED NORTH RIVER BRIDGE AND TERMINAL STATION AT NEW YORK.—At a recent meeting of the American Society of Civil Engineers, the eminent bridge builder, Mr. Gustav Lindenthal, submitted a project for increasing the terminal facilities of the railroads to Jersey City, and reducing the time and risks of the transfer to New York by ferry, by the construction of a six-track supension bridge over the Hudson River, and a short piece of track connecting it with a large depot 400 x 1,000 feet, situated above Eighteenth Street and near Sixth Avenue.

The bridge would have a single span, between pier lines, of 2,850 feet, and be 145 feet in the clear above high water. The entire length, with the approaches, would be about 6,600 feet.

Except for its magnitude, there is nothing experimental in the project, which it is estimated will require five years to complete, and will cost for the terminal station, viaducts, bridge, tunnel and railroad complete, in all about four miles long, ... $23,000,000
The right of way and incidentals, ... 14,000,000

Total, ... $37,000,000

The estimated net annual revenue from the travel "in sight" at the present time, and from rentals, for the first year, is $2,200,000. The design is a stiffened suspension bridge, consisting of parallel cables connected by triangular bracing, as in the bridges of the Schnirch system at Vienna.

To give a better idea of the grandeur of its dimensions, a comparison may be made with the present familiar but unprecedented structure spanning the East River, which is 5,989 feet long, having a clear span, between piers, of 1,595 feet, and a height above water of 135 feet at the centre. Its weight is about 3,600 tons and load 1,400 tons when covered with people and cars, making a total of 5,000 tons. There are four cables each fifteen and one-half inches diameter, and having an ultimate strength of 11,200 tons.

The desirability of a more reliable connection between the shores of the North River was felt as long ago as 1811, when Thos. Pope, an architect of New York, proposed a single span bridge over this broad expanse of water, but he was far in advance of his time. The Hudson River tunnel is another attempt to solve the problem. Still another was a rolling traveller intended to carry an entire train at one time, as described and illustrated in *Engineering News*, of February 23, 1884. Of these several bridge projects, that of Mr. Lindenthal appears the most promising. L. M. H.

A Series of Tests of the Westinghouse Freight-train Brake, similar to those made in other sections of the country, were made on Saturday, November 26th, on the line of the Pennsylvania Railroad, on a portion of the track near Wynnewood Station, in the vicinity of Philadelphia.

From the *Railway World*, of recent date, we make the following abstract:

The train consisted, as in former tests, of fifty freight cars, closely coupled together, each thirty-eight feet four inches in length. In the first test the train, while running at twenty-three miles per hour, was stopped in fourteen and one-half seconds, and a distance of 264 feet. In the second test, the velocity was thirty-six miles per hour; time required to stop, nineteen and one-half seconds; distance, 593½ feet. In the third test, the brakes were applied to the rear cars of the train in about two seconds. In the fourth test, the absence of serious jarring was demonstrated by the presence of passengers on portions of the train, when it was stopped in eighteen and three-fourths seconds, in a distance of 579 feet, while it was running at the rate of thirty-six miles an hour. In the fifth test, the length of time from the stoppage of the train by the brakes, until they were released and the train again started, was three seconds. In the sixth test, five workmen stopped the train in a distance of 1,883 feet. In the seventh test, the train was suddenly broken and the two sections stopped in thirteen seconds, with only thirty-five feet between the sections. In the eighth test, the full power of the brakes was applied to a

train of twenty cars, and while it was running at a rate of twenty and one-half miles per hour, it was stopped, in six seconds, in a distance of eighty-seven feet. The ninth test consisted of a competitive trial with a passenger train, both running at a speed of forty-nine and one-half miles an hour. The freight train was stopped in a distance of 648 feet in nineteen seconds. The passenger train was stopped in twenty-eight seconds and a distance of 932 feet.

As in the preceding tests, conclusive evidence was afforded of the solution of the continuous freight-train brake problem. The fact that it has been solved is of immense importance to the railway interests of the country, whether the subject is viewed from a humanitarian or financial standpoint. The prevailing method of stopping freight trains is probably the weakest point in the mechanical and personal methods applicable to rolling stock and train movements. The reform contemplated, in conjunction with the adoption of an effective automatic coupler system, which will naturally be an accompaniment, forms one of the greatest advances in the practical every-day movements of railroads that has ever been made. An astute foreign railway expert, who found much to admire in American rolling stock, after visiting many portions of the country, denounced the mode generally adopted here of stopping long and heavy freight trains with hand brakemen as a barbarous practice. It not only subjects those men to numerous dangers, which often lead to serious or fatal injuries, but partly on account of the great risks they must incur if they meet all requirements, and partly for other reasons, there are many accidents to freight trains attributable to defective brake-power. The losses from this source represent a sum much greater than any increase of interest or other current outlay that could occur from the adoption of the improved continuous freight-train brakes. By their use, also, it would be safe and practicable to move many freight trains at a higher rate of speed than is now attainable, and thus the amount of work performed by each freight car might be materially increased. The latter consideration should receive due weight in connection with the incessant demand for new cars and the doleful complaints of car famines whenever commercial movements are exceptionally active. It rarely happens that a new invention is at once so complete, and so well calculated to meet pressing needs in wide fields of usefulness, as the improved Westinghouse continuous freight-train brake. W.

MISCELLANEOUS.

THE MAGELLANIC PREMIUM.—The American Philosophical Society at a regular meeting held December 16, 1887, awarded the Magellanic Premium to the author of a paper entitled "On some of the Physical Phenomena of Harbor Entrances" signed by "Magellan." On opening the sealed envelope which, in accordance with the regulations of the Society, contained the name of the author, it was found to be Prof. Lewis M. Haupt of the University of Pennsylvania. E. J. H.

Franklin Institute.

[*Proceedings of the Annual Meeting, held Wednesday, January 18, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, January 18, 1888.

JOSEPH M. WILSON, President, in the Chair.

Present, eighty-seven members and eight visitors.

Additions to membership since the last report, nine.

The annual report of the Board of Managers was read, as follows:

ANNUAL REPORT OF THE BOARD OF MANAGERS FOR THE YEAR 1887.

The Board of Mangers of the FRANKLIN INSTITUTE of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the INSTITUTE for the year 1887.

MEMBERS.

Membership at the close of 1887,	2,222	
Number of new members elected, who have paid their dues,	101	
		2,323
Lost by death or resignation,	68	
Dropped for non-payment of dues,	100	
		168
Total membership at close of 1887,		2,155

FINANCIAL STATEMENT.

Receipts.

Balance on hand January 1, 1887,		$1,100 95
Contributions of members,	$4,677 50	
Received from Guarantee Fund on account of loss incurred by Exhibition of 1885,	823 08	
Sales of property, Exhibition of 1885,	960 00	
Legacy of Henry Seybert (deceased),	2,000 00	
Certificates of second class stock,	70 00	
Fund for completion of serials,	1,130 00	
Interest on investments,	737 00	
Cash from Sale Allotment Pennsylvania Railroad Stock,	64 50	
Cash from other sources,	7,928 99	
		18,391 07
		$19,492 02

Payments.

Committee on Library,	$1,524 87	
Committee on Instruction,	2,566 45	
Exhibition of 1885,	131 12	
Salaries and Wages,	4,423 93	
Maintenance and repairs to building,	1,686 18	
Insurance,	300 00	
Paid on account of temporary loan,	2,000 00	
Interest on temporary loan,	177 36	
Other expenditures,	5,483 62	
		18,293 53
Balance on hand December 31st, 1887,		$1,198 49
Remaining to be paid on temporary loan,	$3,000 00	

An examination of the financial statement will show that the deficiency for the year in expenditure over receipts is very considerable, although apparently the balance on hand remains nearly the same. This is owing to the fact, as may readily be seen, that some of the sources of income are casual for the present year only, and will not obtain in the future, also that moneys have been received for special purposes, such as for completion of serials, and not yet expended. Such funds cannot be applied to maintenance of the INSTITUTE.

The legacy of Henry Seybert (deceased) has been invested as a nucleus towards a "Building Fund."

LIBRARY.

The Library has been increased during the year 1887, by the acquisition of over 3,000 additional titles.

The designation of the Library of the FRANKLIN INSTITUTE by the Department of the Interior as a depository of the publications of the Government, will add to its importance as a library of reference.

For additional details respecting this branch of the work of the INSTITUTE the Board refers to the report of the Committee on Library.

THE JOURNAL.

The JOURNAL of the INSTITUTE has shown itself more than self-supporting during the past year, and its condition is very encouraging.

During the year, the Committee on Publications issued a circular-letter, announcing its intention to publish an index covering the first 110 volumes from 1826 to 1880, inclusive, and inviting subscriptions thereto. The responses to this invitation have been so numerous that the Committee can now undertake this important work without risk of financial loss. By the direction of the Board, the printing of the index will be proceeded with at once, and the work will shortly be ready for distribution to subscribers. This publication will add greatly to the usefulness of the JOURNAL as a work of reference.

The voluntary services of collaborators, which were secured for the JOURNAL last year by the Committee on Publications, have been of considerable advantage, and the thanks of the INSTITUTE are due for this valuable aid.

The Board desires again to call attention to the fact that the JOURNAL is not as generally sustained by the members of the INSTITUTE as it should be, and takes this opportunity to ask for it a more generous support at their hands.

LECTURES.

The following Lectures were delivered during the past year, viz.:—By Prof. C. Hanford Henderson, *one*, on "The Bessemer Steel Process and its Modifications," and *one* on "Glass Making;" by Prof. Chas. F. Himes, *one*, on "The Stereoscope and its Applications;" by Miss Helen C. DeS. Abbott, *one*, on "Plant Chemistry as an Applied Science," and *one* on "The Chemical Basis of Plant Forms;" by Mr. John M. Hartman, *one*, on "The Crucible of the Blast Furnace;" by Prof. Frances Emily White, *one*, on "Hygiene;" by Prof. Henry Trimble, *one*, on "Tannin and its Sources;" by Mr. John Birkinbine, *one*, on "Rainfall and Water Supply," and *one* on "Iron Smelting in the United States;" by Prof. J. Burkitt Webb, *one*, on "Mechanical Paradoxes;" by Mr. Carl Hering, *one*, on "Electricity," and *one* on "The Electrical Transmission of Energy;" by Mr. Wm. F. Durfee, *one*, on "Hero of Alexandria, and the Arts and Mechanism of his Time;" by Prof. Luigi D'Auria, *one*, on "Tidal Rivers;" by Mr. C. O. Mailloux, *one*, on "The Storage of Electrical Energy;" by Commander J. R. Bartlett, *one*, on "The Physical Geography of the Sea;" by Capt. O. E. Michaelis, *one*, on "The Army of Kukuanaland;" by Dr. Persifor Frazer, *one*, "Introductory to the Course on Chemistry;" by Prof. Lewis M. Haupt, *one*, on "Rapid Transit in Cities;" by Prof. Wm. H. Greene, *one*, on "The Mechanics of Chemistry;" by Mr. Chas. E. Emery, *one*, on "Steam Heating in Cities;" by Prof. S. P. Sadtler, *one*, on "Russian and American Petroleum," *one*, on "Present and Prospective Sources of Sugar," and *one* on "The Manufacture of Artificial Dye Colors;" by Mr. C. J. Hexamer, *one*, on "The Yellowstone Park;" by Prof. Wm. A. Anthony, *one*, on "Electrical Measurements;" by Thomas Pray, Jr., *one*, on "The Cotton Fibre;" by Mr. John Birkinbine, *one*, on "The Iron Ores of the United States;" and by Prof. J. E. Denton, *one*, on "The Construction of the Great Croton Aqueduct."

The foregoing list embraces thirty-two lectures. The Professors of the INSTITUTE, with the co-operation and endorsement of the Committee on Instruction, have spared no efforts to maintain the high character for which the lectures of the past few years have been notable.

DRAWING SCHOOL.

The Drawing School has shown considerable increase over the attendance of the previous year, and its efficient management, together with the marked interest of the students in their work, gives the assurance that this valuable adjunct to the INSTITUTE will continue to be successful.

The attendance for the Spring Term of this year was, ...	192	
And for the Fall Term, ...	224	
	416	
Making an increase over the previous year of, ...		11

COMMITTEE ON SCIENCE AND THE ARTS.

The impending changes in the constitution of the Committee which were noted in last year's report, the most noteworthy of which was the making of the Committee an elected body with a fixed number of members (forty-five), in place of the voluntary association of former years, went into effect in January of the past year.

The reorganized Committee included in its membership a number of the most capable and active members of the INSTITUTE, and the Board feels warranted in congratulating the INSTITUTE on a change which gives promise of greatly increasing the usefulness of this Committee.

During the year, the Committee considered seventeen new applications and reported upon nine, and has nine cases under consideration at the present time. In two of these cases the Committee awarded Certificates of Merit; in one case the Elliot Cresson Medal, and in two cases recommended the award of the John Scott Legacy Premium and Medal.

REORGANIZATION AND FUTURE WORK.

The Committee on Reorganization having completed the revision of the By-Laws, and provided for the creation of a Board of Trustees, it remains that these Trustees be elected—a proceeding that it would be advisable the Board of Managers should carry out as soon as practicable.

It is within the province of this Committee on Reorganization to continue its work in the matter of formulating and reporting "what should be the future work of the INSTITUTE," and also to prepare plans for a suitable building in which the INSTITUTE can carry out that work, and it is of the utmost importance that the Committee should continue its labors to a conclusion.

The wants of the INSTITUTE are vital. It is a great and noble institution, worthy of the name it bears, and doing invaluable work for the City of Philadelphia and for the world.

Yet it is embarrassed in every direction; for want of room in its building, want of conveniences in its educational departments, and, above all, want of funds. Every year its accounts present a deficiency. This cannot go on forever. Unless some change takes place for the better, the day will surely arrive, although it is hoped it may be far off, when its doors will be closed. Cannot those who are interested in the promotion of educational privileges, and who have the means to make a practical application of their interest, have their eyes opened to the field here presented?

Under the reorganization, the system of the INSTITUTE is in the best shape possible for such aid. Its Managers, its Officers and its Professors are active, reliable, energetic and economical, doing all they can with the least possible expenditure; but, it may as well be plainly spoken, it is money that is wanted, money, properly and securely vested in the hands of its Trustees, the income to be rightly applied to the continuance and advancement of the INSTITUTE. From an examination of the expenditure account it will be evident to anyone that a decrease in these expenditures cannot readily be made without seriously crippling the efficiency of the INSTITUTE.

New and more extensive buildings are needed. The Library has far outgrown its quarters. Here is one of the most valuable purely scientific libraries of the country, proving its usefulness for consultation and reference every day, containing many volumes that, if destroyed, could never be replaced, and yet in a building not even fire-proof.

Cannot a systematic effort be made to improve this state of things? The INSTITUTE asks for aid. Shall its appeal be in vain?

By Order of the Board, JOS. M. WILSON, *President.*

The Committee on Library made the following report:

THE COMMITTEE ON THE LIBRARY respectfully report, that during the year 1887 there have been added to the Library:

Volumes, bound,	2,099
Volumes, unbound,	448
Pamphlets,	1,120
Total,	3,677
Maps and charts,	108

The above is exclusive of duplicates, of which a large number were acquired during the year, as follows:

Volumes, bound,	618
Volumes, unbound,	90
Pamphlets,	863
Total,	1,571

TOTAL NUMBER OF VOLUMES IN THE LIBRARY. Taking the statement of the Librarian at the close of the year 1886, as, ... 27,998 volumes,
and adding the additions of 1887, ... 3,667 "

We have a total of . . . . 31,665 "

which is exclusive of a pamphlet collection of about 8,000, classified, catalogued and accessible for reference.

THE B. H. MOORE FUND.—There have been purchased during the year from the income of this fund 317 volumes, and one pamphlet and chart, at an expenditure of $424.96, leaving an unexpended balance of $75.04.

DUPLICATES.—During the past year duplicates have been disposed of to

the value of,	$174.89
And books received in exchange to the value of,	141.10
Leaving to the credit of the account,	$33.79

SERIALS.—During the year the following important ones were completed:

The American Gas Light Journal.

"Proceedings of the American Gas Light Association."

"Proceedings of the Society for Psychical Research."

"Transactions of the American Institute of Electrical Engineers."

Through the liberality of the members and friends of the INSTITUTE, the sum of $1,135 has been subscribed and deposited with the Treasurer to be applied to the completion of the more important serials in the library. The committee has been in correspondence with book dealers in Europe, and has now the invoices of the first shipment, amounting to about $600, towards the furtherance of this important work.

GOVERNMENT PUBLICATIONS.—By the courtesy of the Moyamensing Literary Institute, of this city, there have been transferred to the Library of the FRANKLIN INSTITUTE the Government publications deposited with that institution, amounting to 1,629 volumes. Having relinquished in favor of the FRANKLIN INSTITUTE the designation as a public depository, the Hon. Sam'l J. Randall has directed the transfer to be made in the Department at Washington. The annual addition to the library from this source will be voluminous, and added to the collection of former years, will form a valuable library of Government publications, freely accessible to the public.

WANT OF ROOM AND PROPER PROTECTION for the most important library of scientific and technical publications in the United States continues to be a source of solicitude to your committee. The time has now arrived when the question will have to be considered, whether to check the increase of the library to accommodate it to its restricted quarters, or to provide a suitable building for its expansion and preservation, which shall afford ample space for its natural increase, and comfort and convenience to the members of the INSTITUTE and to the public, to whom the Library is accessible.

CHAS. BULLOCK,
Chairman of Committee on Library.

The Chemical and Electrical Sections likewise presented detailed reports of their operations during the year 1887.

The foregoing reports were severally accepted.

MR. W. U. WOODRUFF, of Hartford, described the advantages of a new system of keying for machinery, which he had devised and proposed as a standard, and illustrated the subject by the exhibition of a complete set of cutters and keys. The subject of Mr. Woodruff's communication has been referred to the Committee on Science and the Arts, for an investigation and report thereon.

PROF. EDWIN J. HOUSTON made an oral communication on the "Paillard Non-Magnetizable Watch," giving an account of a series of tests to which he had subjected it, and which fully confirmed the claims of the inventor.

The SECRETARY read his annual report, which appears elsewhere in the JOURNAL.

The following preamble and resolution were unanimously adopted, on the motion of PROF. LEWIS M. HAUPT, viz.:

WHEREAS, During this first century of our national existence, the public civil works conducted by the various departments of the General Government, have reached such magnitude and importance as to require a greater economy and efficiency of administration; and,

WHEREAS, The present promiscuous assignment of technical bureaus to departments for which they have no affinity; the reduplication of services; the frequent changes in the *personnel;* the failure in passing the appropriation bills and resulting disorganization of the employés, and the absence of personal responsibility, are not conducive to such economy and efficiency; and

WHEREAS, The FRANKLIN INSTITUTE of the State of Pennsylvania, for the promotion of the Mechanic Arts, has ever maintained a deep interest in the development of the mechanical and civil industries of our country, and desires to encourage and promote a more systematic organization of these important bureaus on the part of the General Government; therefore,

Resolved, That the FRANKLIN INSTITUTE respectfully but urgently requests the members of the Fiftieth Congress of the United States to enact such laws as will result in a more efficient and systematic organization of the numerous technical bureaus and greater economy of administration in the conduct of the Public Civil Works of the Government.

The result of the annual election for officers, managers and members of the Committee on Science and the Arts is given below:

President (to serve one year), ... JOSEPH M. WILSON.
Vice-President (to serve three years), ... W. P. TATHAM.
Secretary (to serve one year), ... WM. H. WAHL.
Treasurer (to serve one year), ... SAMUEL SARTAIN.

Managers (to serve three years): Hugo Bilgram, Cyrus Chambers, Jr., G. Morgan Eldridge, Henry R. Heyl, Chas. Hare Hutchinson, Samuel R. Marshall, Chas. E. Ronaldson, William Sellers.

Auditor (to serve three years), Lewis S. Ware.

Members of the Committee on Science and the Arts (to serve three years): J. M. Emanuel, Prof. L. B. Hall, John Haug, Henry R. Heyl, C. W. Howard, Fred. E. Ives, W. M. McAllister, H. Pemberton, Jr., Philip Pistor, Prof. S. P. Sadtler, T. C. Search, Thomas Shaw, Louis H. Spellier, W. Rodman Wharton, Moses G. Wilder.

Adjourned. WM. H. WAHL, *Secretary.*

LIST OF BOOKS

PRESENTED TO THE LIBRARY.

(*Continued.*)

Massachusetts. Annual Reports of the Commissioner of Insurance for 1885. Part 2. Life, etc. Boston. Presented by the Commissioner.

Massachusetts. Board of Commissioners of Savings Banks. Annual Reports for 1876 and 1882. Boston, 1877 and 1883. Presented by the State Librarian.

Massachusetts. Census of 1875. Vols. 1 to 3. Boston, 1876–77. Presented by the State Librarian.

Massachusetts. First Annual Report of the State Agricultural Experiment Station at Amherst. 1883. Boston, 1884. Presented by the Director.

Massachusetts. Forty-third Report Relating to the Registry and Return of Births, Marriages and Deaths in the Commonwealth for 1884. Boston, 1885. Presented by the Secretary of State.

Massachusetts. History of Wages and Prices. 1752–1883. By E. D. Wright, Chief of Bureau of Statistics of Labor. Boston, 1885. Presented by the Chief of Bureau.

Massachusetts. Manual for the Use of the General Court. Boston, 1685. Presented by the State Librarian.

Massachusetts. Registry and Return of Births, Marriages and Deaths, etc. Second; Fourth to Sixth; Eighth to Fourteenth; Seventeenth, Eighteenth, Twenty-ninth and Thirty-third. Annual Reports. Boston. Presented by the State Librarian.

Massachusetts. Report of a Commission Appointed to Consider a General System of Drainage for the Valleys of Mystic, Blackstone, and Charles Rivers. Boston. Wright & Potter Printing Company. 1886. Presented by the Chief Engineer.

Massachusetts. State Agricultural Experiment Station. Bulletins Nos. 16, 17 and 19. 1885–6.

Massachusetts. State Agricultural Experiment Station. Second Annual Report. 1884. Amherst, 1885. Presented by the Director.

Massachusetts State Board of Health, Lunacy and Charity. Sixth and Seventh Annual Reports. Boston. Wright & Potter Printing Company. 1885–86. Presented by the Board.

Massachusetts State Library. Annual Report of the State Librarian for 1885. Presented by the State Library.

Massachusetts. Statistical Information Relating to Certain Branches of Industry, 1855 and 1865. Boston, 1856 and 1866. Presented by the State Librarian.

Master Car-Builders' Association. Reports of Proceedings of Eighth, Ninth, Eleventh to Fifteenth, and Seventeenth and Eighteenth Annual Conventions. New York, 1874–84. Presented by M. N. Forney, Secretary.

Matteucci Carlo. Living Beings. Philadelphia, 1848.
Presented by Mrs. Wm. B. Rogers.

Maury, M. F. Physical Geography of the Sea. Second Edition. Enlarged and Improved. New York, 1855. Presented by Mrs. Wm. B. Rogers.

Mayor of Philadelphia. Annual Report of Wm. B. Smith, for 1884.
Presented by his Honor, the Mayor.

Memorial Record of the Fathers of Wisconsin. Madison, 1880.
Presented by the State Historical Society.

Memphis and Charleston Railroad Company. Twenty-ninth and Thirtieth Annual Reports of Directors for 1883–84. Presented by the Company.

Mendenhall, Geo. The Medical Students' Vade Mecum. Philadelphia, 1847.
Presented by Mrs. Wm. B. Rogers.

Mérat, F. V. et A. J. De Lens. Dictionnaire Universelle de Matière Médicale, et de Therapeutique Générale. Paris, 1829–34.
Presented by Mrs. Wm. B. Rogers.

Meriden. City of. Revised and Amended Charter and By-Laws. 1882.
Presented by the Mayor.

Merriman, M. Mechanics of Materials. N. Y., 1 : 1885.
Presented by John Wiley & Sons.

Meteorological Committee of the Royal Society. Annual Report for 1885. London, 1886. Presented by the Society.

Meteorological Council. Royal Society. Contributions to our Knowledge of the Meteorology of the Arctic Regions. Part 4. Vol. 1. London, 1885.
Presented by the Royal Society.

Meteorological Council. Royal Society. London. Hourly Readings. January to March, 1883, and April to June, 1885.
Presented by the Council.

Meteorological Council. Royal Society. Monthly Weather Report for March, April and May, August to December, 1885. London, 1885.
Presented by the Council.

Meteorological Council. Royal Society. Official No. 66. Meteorological Observations at Stations of the Second Order for 1881. London, 1886.
Presented by the Council.

Meteorological Council. Royal Society. London. Quarterly Weather Report of the Meteorological Office, July to December, 1877; January to March, 1886. Presented by the Council.

Meteorological Council of the Royal Society. Weekly Reports from April to September and December, 1885. April 19th to July 5, 1886.
Presented by the Council.

Meteorological Department. Government of India. Indian Meteorological Memoirs. Vol. 3, Part 1; and Vol. 4, Part 1.
Presented by the Department.

Meteorological Observations Recorded at Six Stations in India. February and March, June to August and December, 1885, to February, 1886.
Presented by the Department.

Meteorological Observations. India. Registers of Original Observations in 1885. Reduced and corrected. January, 1885.
Presented by the Meteorological Department.

Mialke. Chimie. Paris, 1856. Presented by Mrs. Wm. B. Rogers.

Michigan. Annual Report of the Board of State Auditors for the State of Michigan for the Year 1883. Lansing, 1884.
Presented by the Secretary of State.

Michigan. Annual Reports of the Bureau of Labor and Industrial Statistics. February 1, 1884–85. Lansing.
Presented by the Secretary of State.

Michigan. Annual Reports of the Commissioner of Mineral Statistics for 1880–82 and 1884. Marquette & Lansing, 1880–84.
Presented by His Excellency the Governor of the State, R. A. Alger.

Michigan. Annual Reports of the Commissioner of Railroads for 1875, 1878, 1880, 1883 and 1884. Lansing. Presented by the Commissioner.

Michigan. Annual Report of the Commissioner of the State Land Office for the Fiscal Year Ending September 30, 1884. Lansing, 1885.
Presented by the Secretary of State.

Michigan. Board of State Commissioners for the General Supervision of Charitable, etc., Institutions. Second, Third, Fifth, Sixth, and Abstract from Seventh Biennial; and Annual Reports for 1874, 1876, 1879–80, 1881–82, 1885–86. Lansing. Presented by the Secretary of State.

Michigan Board of State Commissioners for the General Supervision of Charitable, Penal, etc., Institutions. Report and Special Report. Lansing, 1873 and 1872.

Michigan. Fish and Game Laws. Lansing, 1881.

Michigan. First to Sixth Annual Reports of Secretary of State on Farms and Farm Products, 1878–9, 1883–4. Lansing, 1880–84.

Michigan. General Railroad Laws, and Digest of Decisions of the Supreme Court, 1881. Lansing. Presented by the Secretary of State.

Michigan. Geological Survey. Reports. Vols. 1 to 4, and Atlas. New York, 1873–81. Presented by the State Library.

Michigan. Joint Documents of the State Containing the Annual Reports of the Heads of Various State Departments, 1858–83. Lansing, 1859–84.

Michigan. Laws Relating to the Incorporation of Manufacturing Companies. Lansing. Presented by the Secretary of State.

Michigan. Proceedings and Addresses at Sanitary Convention, held March 19 and 20, 1885. Lansing, 1885.
Presented by the State Board of Health.

Michigan. School for the Blind. Second Biennial report of the Board of Commissioners. Lansing, 1885.

Michigan. Seventeenth Annual Report relating to the registry and return of Births, Marriages and Deaths for the year 1883. Lansing, 1885. And extracts from the reports of the Board of Health.
Presented by the Secretary of State.

Michigan. State Agricultural College. Catalogues of Officers and Students. Twenty-eighth year. 1884–85. Presented by the President.

Michigan. State Board of Agriculture. Twenty-third Annual Report of the Secretary from October 1, 1883, to September 30, 1884. Lansing, 1884.
Presented by the Secretary.

Michigan. State Board of Corrections and Charities. Seventh Biennial Report, 1883–84. Lansing, 1885.
Presented by the Secretary of State.

Michigan. State Board of Health. Twelfth Annual Report of the Secretary for 1884. Lansing, 1885. Presented by the Secretary.

Michigan. State Horticultural Society. Annual reports of the Secretary for 1881–84. Lansing, 1882–85.

Michigan. State Mining Law of 1877. Lansing, 1881.

Michigan. State Pomological Society. Annual Reports for 1872–75–76 to 1880. Lansing, 1873–81.

Michigan. State Prison. Annual Report of the Inspectors and Officers for the year closing September 30, 1884. Lansing, 1884.

Michigan. The General School Laws, with Appendices. 1881. Lansing.

Michigan. The Liquor Laws of the State. Lansing, 1881.
Presented by the Secretary of State.

Milano. Atti del Collegio degli Ingegneri ed Architetti in. May–September, 1885. Three parts. Presented by the Society.

Milwaukee Board of Public Works. Annual Reports for 1883–1885. Milwaukee, 1886. Presented by G. H. Benzenberg, City Engineer.

Milwaukee, Wis. Annual Reports of the City Comptroller, containing the Reports of the Water Department and Board of Public Works. 1873, 1874, 1876, 1877, 1878, 1882 and 1883. Presented by the Comptroller.

Mineral Products of the United States. Calendar Years 1882 to 1884. By Albert Williams, Jr. Presented by the U. S. Geological Survey.

Mineral Waters. By A. C. Peale. U. S. Geological Survey. Washington, 1885. Presented by the Survey.

Mining Exhibition, under the Auspices of the Mining Institute of Scotland, held 1st till 24th September, 1885. Official Catalogue of Exhibits. Hamilton, 1885.

Mining Institute of Scotland. Report Relative to the Mining Exhibition in Glasgow. September, 1885.

Mining Institute of Scotland. Transactions. Vols. 1 to 6 inclusive, complete; and Nos. 1 to 3 of Vol. 7. Hamilton, 1879 to 1885.
Presented by the Institute.

Minnesota. Geological and Natural History Survey. Thirteenth Annual Report, 1884. St. Paul, 1885.

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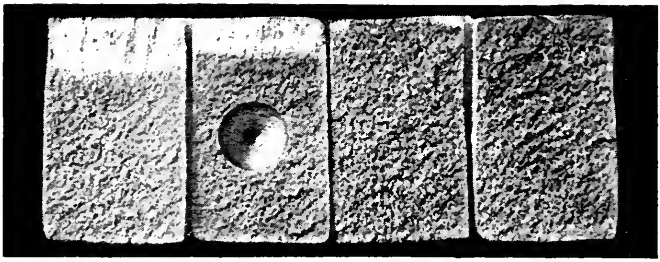

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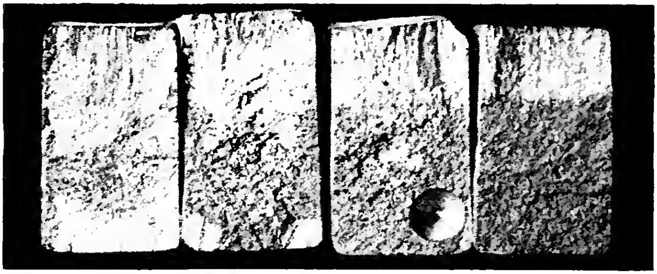

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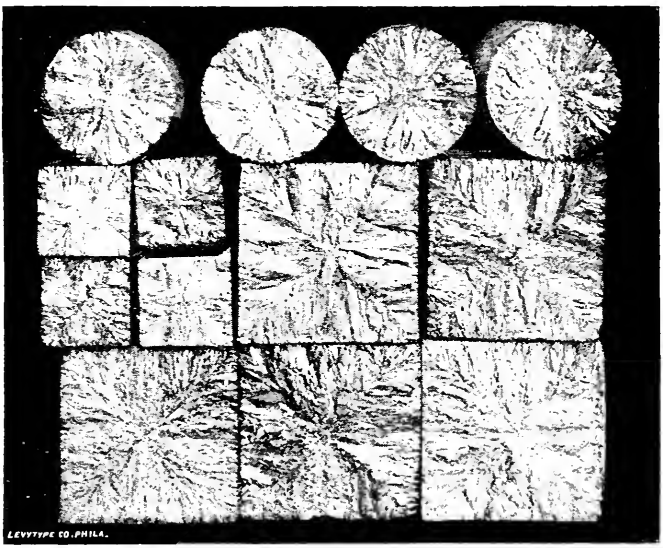

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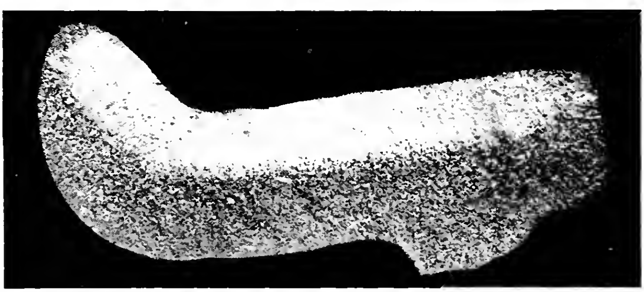

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SCREW-THREADS.

BY JOHN L. GILL, Jr., Philadelphia, Pa.

[*Read at the Stated Meeting, Wednesday, November 16, 1887.*]

JOSEPH M. WILSON, President, in the Chair.

The subject of screw-threads has been discussed by engineers and machinists for so long a time, and so continuously, that it might seem as though it would be worn 'thread'-bare, but until a form of thread is adopted that can be more readily produced of a standard size, and more easily maintained than the threads now in common use, the theme will continue to be a good subject for discussion.

During the year of 1857, Sir Joseph Whitworth, of England, prepared a table for screw-threads having a particular form, and offered it to the engineers of Great Britain, with a recommendation that it be adopted as an interchangeable system throughout the Kingdom. It was received with favor, and has been generally adopted in Great Britain, with good results.

In the year 1864, Mr. Wm. Sellers, then the President of the FRANKLIN INSTITUTE, read a paper before the INSTITUTE on the importance of having an interchangeable system in this country. He described the Whitworth system, and explained some of its advantages and defects, and proposed a system of his own, using about the same number of threads per inch as Whitworth's, but substituting a flat top and bottom for the rounded ones, and changing the angle of the sides from 55° to 60°.

A committee was appointed to examine the system, and make a report thereon.

This committee reported in favor of the system, and the INSTITUTE requested the manufacturers of the country to adopt it.

Much good has resulted from this recommendation, and yet an immense amount of trouble has been brought about by it.

The necessity at that time for an interchangeable system was so great, that any practicable plan proposed by a well-known authority would have been hailed with delight.

The number of threads per inch proposed in the Sellers table was probably a fair average of those in use, but the slight change in shape from the common V-thread, then in use, was so difficult to obtain in practice, that the system has been very slow in coming into general use. It is now nearly twenty-four years since it was introduced, and still, at this time at least, twenty or twenty-five per cent. of the manufacturers of the country do not use it, preferring, for one reason or another, to use systems of their own.

The most extensive manufacturers of bolts and nuts in this locality—the well known firm of Hoopes & Townsend—did not adopt the Sellers system till 1881, although they had, for years before, supplied such of their customers as required it, with bolts and nuts having this thread.

Referring to the Transactions of the INSTITUTE for April of 1887, it appears that the engineers of the United States Army and Navy adopted the system in 1869, the Master Mechanics' Association in 1870, the Master Car Builders' Association in 1872, and although all the railroads in the country are represented in these two associations, some of the most extensive railroad corporations did not adopt the system till years later. The Chicago, Burlington and Quincy, the Chicago, Rock Island and Pacific, and the New York Central and Hudson River Railroad adopted it in 1883.

Since the exchanging of cars from one road to another has become so universal, the necessity for an interchangeable system of bolts and nuts has grown more apparent; and all the roads are falling into line in adopting the Sellers system, not because the system is considered perfect or altogether satisfactory, but from necessity.

The members of the two associations, the Master Car Builders and Master Mechanics, having charge of the rolling stock of all the railroads in the United States, know better how to appreciate the benefit to be derived from having an interchangeable system of bolts and nuts, than any other class of mechanics, as they are called upon every day in the year to furnish bolts or nuts to replace those lost or broken, on the rolling stock of what are termed foreign cars, while in use on the roads of which they have charge. It is quite probable that these men use more bolts and nuts, than all the rest of the mechanics in the country combined.

It has been found that nearly all the railroads of this country use the Sellers system, so far as the number of threads is concerned, yet many of them do not use the other dimensions. Some of them use taps considerably over-size, and some do not use the flat top and bottom.

The principal difficulty in obtaining taps and dies of the Sellers form and size, is owing to the thread being made in section, a trapezoid, whose base is made equal to the pitch of the threads, less a distance equal to the flat top, and whose altitude or height is necessarily the fractional part of an inch, that is almost always a decimal fraction in the thousandths, or else an indeterminable measure.

As it is impracticable to measure in the ordinary machine shop closer than the one-thousandth part of an inch, the figures after the third decimal are left off, usually adding one to the third figure, if the fourth is five or over. A difference of five ten-thousandths of an inch will make a tight or loose fit.

Sir Joseph Whitworth stated in one of his addresses before the Society of Civil Engineers, in 1857, that one ten-thousandths of an inch in difference in the diameters of a plug and ring, made a loose fit; and illustrated the fact by exhibiting a pair of gauges.

I have before me a steel bolt with a nut fitted to it, of which both diameters, in the nut, are one-thousandth of an inch larger than the corresponding diameters of the bolt. On showing it to a member of the Institute, who was a member of the committee in

1864, he remarked that I should have required better workmanship. At the time this bolt was made, I had determined to keep the size of the bolt the same as that given in the table, and to make the diameters in the nut larger than on the bolt, otherwise the nut could not be put on the bolt. I was at a loss to know what difference to recommend, and I failed to get any light on the subject till I found out by experiment. I was aware that a car axle turned from four- to six-thousandths of an inch larger than the hole in a car wheel, would require from twenty to thirty tons pressure to force it into the wheel, while two or three thousands still larger for the axle would burst the wheel.

I had nuts chased four-thousandths, two-thousandths, and one one-thousandth of an inch larger than the bolt. The first two were much too large, and the latter is loose enough to justify the above criticism. It is my impression, however, that one-thousandth would not be too large in practice using iron for bolts and nuts; for a little oil on the bolt, and any roughness that might remain on the thread would cause it to turn tight enough.

Going back again to the Sellers thread, the width of the flat surface at the top and bottom of the thread is necessarily so small that it can not be measured, and can only be obtained by the fit-and-try process. This flat surface must be exactly right, otherwise if the tool used for chasing the thread was too wide, the fit would be too loose; if too narrow, the fit would be too tight.

I have prepared a chart, illustrating the different kinds of threads, showing their exact shapes and comparative proportions.

This chart is made to represent the thread on a bolt one inch in diameter, with eight threads to the inch. The part that is section-lined represents the thread in the nut.

You will observe the Whitworth thread with its 55° angle and its top and bottom rounded.

The altitude of the triangle thus formed, with its apex having an angle of 55°, is considerably greater than that formed with an angle of 60°, but when the altitude is divided by six, and two-sixths are removed, the remaining four-sixths are very nearly equal to the remaining six-eighths of the triangle of the Sellers form after the two-eighths have been removed.

I have drawn some dotted lines over one of the threads of the Sellers form, to represent the Whitworth thread.

You will see that there is so little difference, that the nuts of one form will probably fit the bolts of the other, and it is quite likely that, in practice, taps and dies made in a common shop, to be either a Whitworth or a Sellers form, would be as near one as the other. Since writing the above, I have been informed by a member of the committee of 1864, that locomotives built in this city for use on the roads of Canada, have bolts with the Sellers form of thread, and when they need repairs, nuts of the Whitworth standard are used on the bolts, and are found to be equally serviceable.

A prominent maker of bolts and nuts has informed me that they make a great many bolts for foreign orders that require the Whitworth standard thread; that they make them to the Whitworth gauge as near as it is possible to work, but they do not have to make special nuts, as they find the nuts from their common stock, with Sellers thread, to answer just as well.

It is claimed that the 60° angle of the Sellers thread is more easily found than an angle of 55°. This is, of course, true, but if a tool ground perfectly to an angle of 60° is not properly placed in the tool post of the lathe, it will not cut a thread with an angle of 60°. As bolts that are not perfectly cut are in very common use, and do not cause much trouble, the question is not an important one. The width of the flat or rounded surface is so infinitesimally small that the difference between them is of little importance, and the difficulty claimed by some in making is more imaginary than real.

The *greatest difficulty* in obtaining a standard size and form of thread applies to the V-form, the Sellers, or the Whitworth form alike. It is the difficulty in calipering the diameters at the top and bottom of the threads in the nuts and on the bolts. If the bearing surface of the threads does not correspond exactly in the nut and on the bolt, they soon adjust themselves when a strain is applied, but if the nut is too loose there is no remedy.

Most manufacturers make the hole in the nut too large for the bolts for which they are intended. This is done for the purpose of making the taps last as long as possible. The result is that the thread of the bolt only bears on its outer edge. On examining any commercial list of nuts, it will be found that the hole in the nut is so large that the thread is only half the depth of the thread on the bolt.

One of the difficulties in the way of getting taps of a uniform size, is owing to the fact that all steel does not expand alike in hardening and tempering; consequently, a difference in size will be found in a lot of taps that have been made with the greatest care.

One of the largest manufacturers of bolts and nuts in the city informs me that they order upward of 100 taps at a time of one size, and when they are received they carefully gauge them and make two or more sizes, and use them of the different sizes for special purposes.

The many difficulties experienced make it impossible for any ordinary machine shop to verify the standard, except by comparing with standard gauges that only one shop in the United States (so far as I am aware) attempts to make.

There are quite a number of manufacturers that make taps for sale; some make very good ones, and some make intolerably bad ones. No shop not especially prepared can afford to make its own taps. The taps of the best manufacturers vary in size and unless the purchaser can afford to have a set of expensive gauges he cannot tell which are right, the large ones or the small ones.

The Sellers or the Whitworth system answers very well where the bolts are chased in a lathe in a comparatively small way, and where bolts and nuts are used of a size much larger than necessary for the purpose, and where economy in the use of material is not considered, but when bolts have to be cut on a bolt-cutter by the thousand, it is behind the age. These criticisms apply with equal force to the Whitworth thread.

A good system of threads for use in bridge work, car building and common machinery construction, that would be interchangeable and give at the same time from twenty to thirty per cent. more strength to the bolts—than those in common use—is practicable and desirable. To have a thread suitable for all kinds of work is not practicable.

The pipe manufacturers have a system of their own—a very good one. Neither the Sellers nor the Whitworth system is applicable to pipe work. For long lines of pipe, the manufacturers use a taper thread by which tight work may be more easily obtained, and the greatest strength at the couplings secured.

This kind of thread was used in the couplings for splicing the wires in the cables of the Brooklyn bridge, whereby ninety-five per cent. of the strength of the wire was obtained.

While engaged in car building some years since, I gave the subject considerable attention, and in the year 1879, I made some tests, of which I will give an account.

It occurred to me that the bolts in common use were weakened more than was necessary in cutting the Sellers thread on them, and the nuts were more than twice as strong as the bolt, for it was known that a nut, the thickness of one-half of the diameter of the bolt, would break the bolt without stripping when a strain was applied great enough to destroy one or the other; so I considered the question whether it was not possible to equalize the strength of the bolt and nut by making a thread with less depth.

When describing the Sellers thread, it is said that the height of the V is divided by eight, the top eighth removed, and the groove at the bottom filled up one-eighth. This gives an idea of the shape of the thread, but it does not convey to the mind its most valuable feature, namely, the increasing of its cross-section at the base of the thread, whereby the strength of the bolt is increased from seven to twenty per cent. over the V-thread bolt.

On examining the question, I found that two-eighths of the altitude might be removed and the groove filled up two-eighths; that on a bolt one inch in diameter this would increase the strength of the bolt more than fifteen per cent. over the Sellers bolt of the same size, or thirty per cent. over the V.

I had three taps made, all of the same size, one inch in diameter, all of the same pitch, viz.: eight threads to the inch, and all having the same angle of 60°. One with the ordinary V-thread, one with the Sellers thread, and one with my experimental thread. On examining the dimensions of the different bolts, the diameters at base of the threads were found to be, respectively, ·784, ·838 and ·892; and their areas of cross-section at the base of the thread, ·4827, ·5515 and ·6249, respectively. Cutting the V-thread reduces the cross-section about thirty-eight per cent.; cutting the Sellers thread, about thirty per cent., and my experimental thread, about twenty per cent. of the full section.

The bolt having the Sellers thread is found to be fourteen per cent. stronger than the V, and my experimental bolt thirteen per cent. stronger than the Sellers, or thirty per cent. stronger than the bolt with the V-thread.

The specimens were prepared as follows: four rods, eighteen inches long, rough as they came from the mill, one and one thirty-second of an inch in diameter, and four rods turned down to one inch in diameter. These were used to test the quality of the iron.

Twelve specimens each, having the three different threads on them.

Not to trouble you with all the figures, I will say, briefly, that each specimen was broken in the small section at the bottom of the thread, with a load corresponding in almost exact proportion to its quality and cross-section. The breaking strain of the specimens averaged as follows:

Bolt having V-thread, ...	24,300 pounds.
Bolt having Sellers thread, ...	27,000 "
Bolt having my experimental thread, ...	31,600 "

As the specimens having the V-thread resisted a load fully equal to the others in proportion to size, the long-prevailing idea, that a bar of iron is weakened in excess of the reduction of its cross-section, by having a sharp groove cut into it, was thus shown to be erroneous.

The rods having the scale turned off withstood a load in a proportion of their cross-sections, equal to the rods that were not turned down. This, with the observation of other experimenters, that the scale always cracks off of the specimens as soon as the elastic limit is reached, proves that iron is no stronger with the scale on, than when it is removed.

After breaking all the specimens, it was found that not one of the nuts could be run forward a part of one thread, except on three or four of the specimens, which broke inside of the nut. Yet all of the nuts could be easily run off in the opposite direction with the thumb and finger. This proved conclusively that none of the threads were injured materially while resisting a strain that broke all the specimens.

I tested the forty-eight inch specimens for the elastic limit in the full section. All the specimens having the V-thread broke before the elastic limit was reached.

I detected it only in one specimen in the rods having the Sellers thread.

All of the specimens having my experimental thread stretched considerably before breaking.

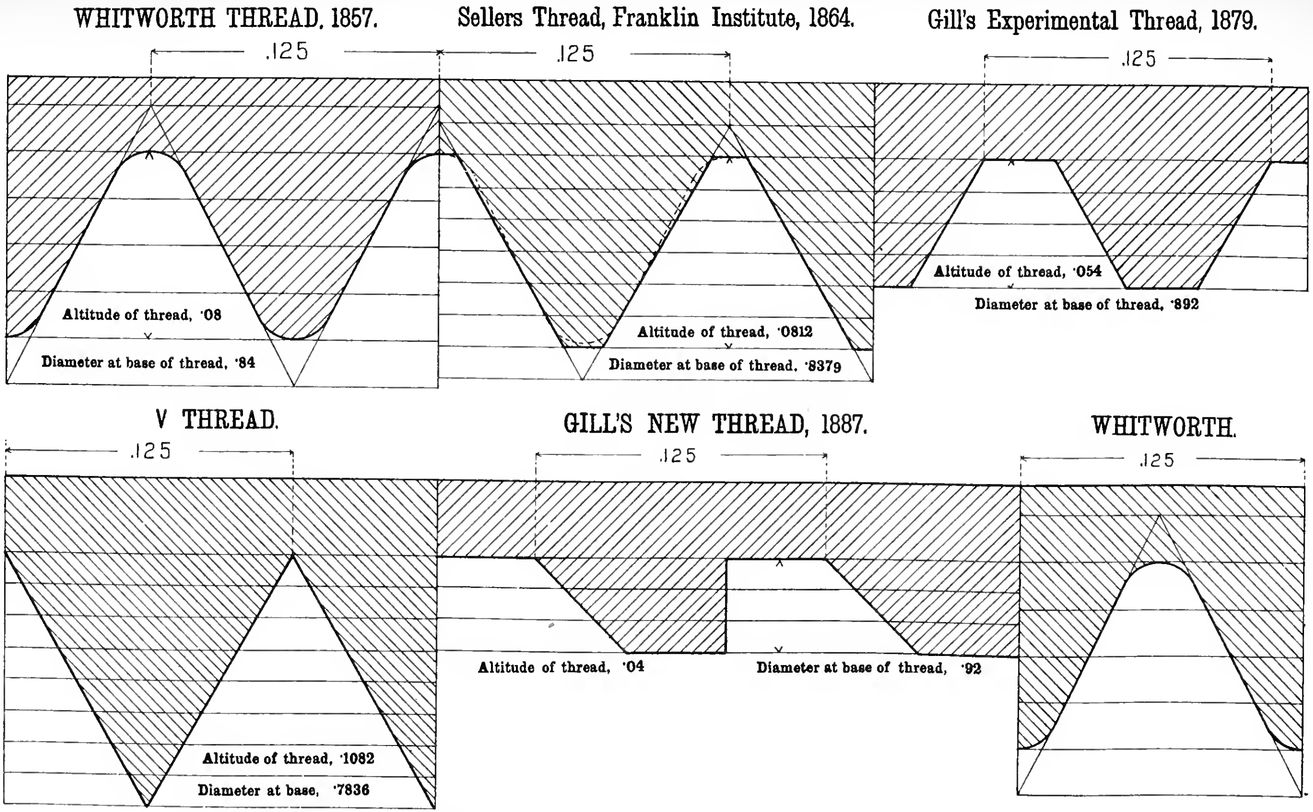
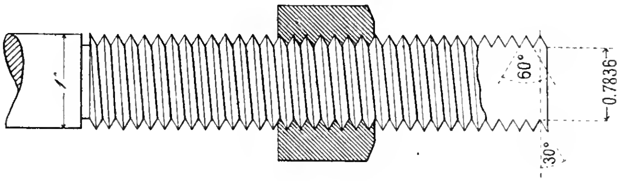
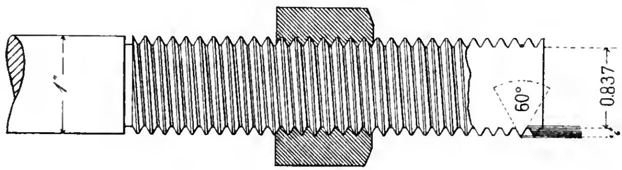


Chart of Screw Threads. Bolts one inch in Diameter, by John L. Gill, Jr.

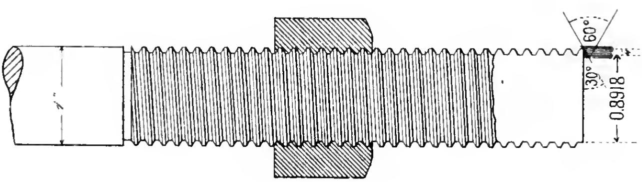
V THREAD.



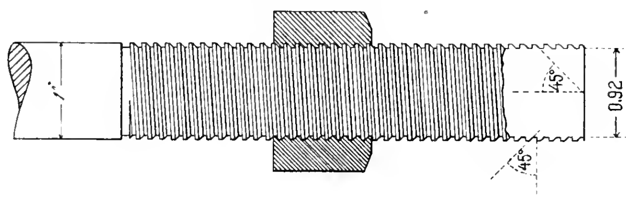
Sellers or Franklin Institute Thread, 1864.



Gill's Experimental Thread, 1879.



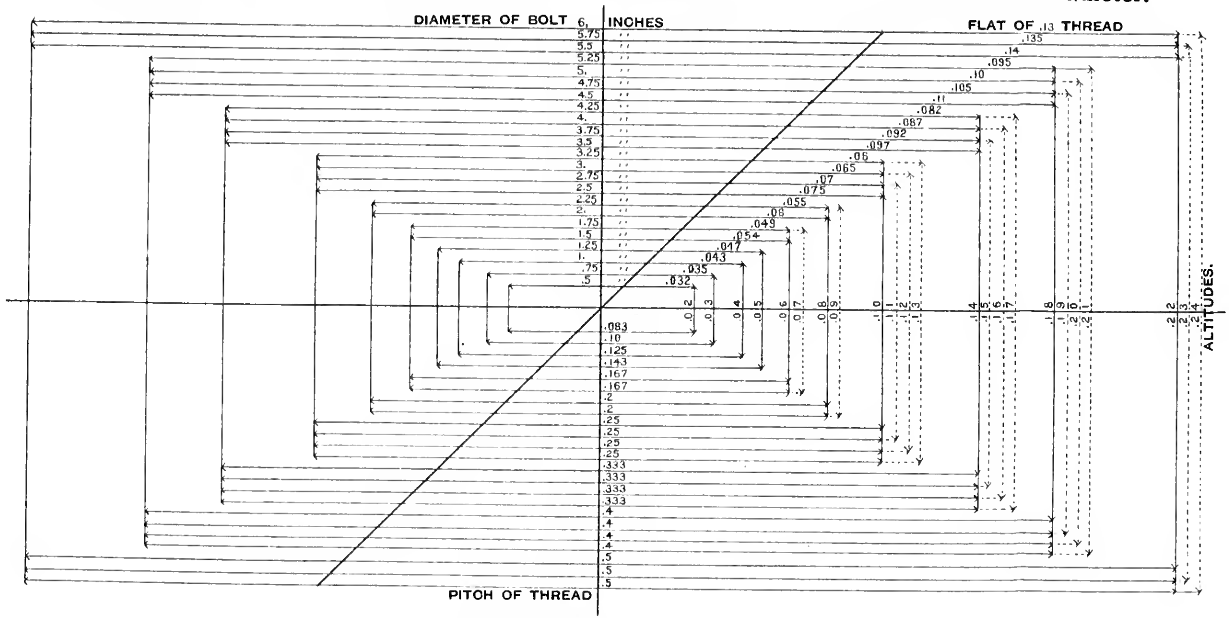
Gill's New Thread, 1887.



Screw Threads in Section by John L. Gill, Jr., June, 1887.

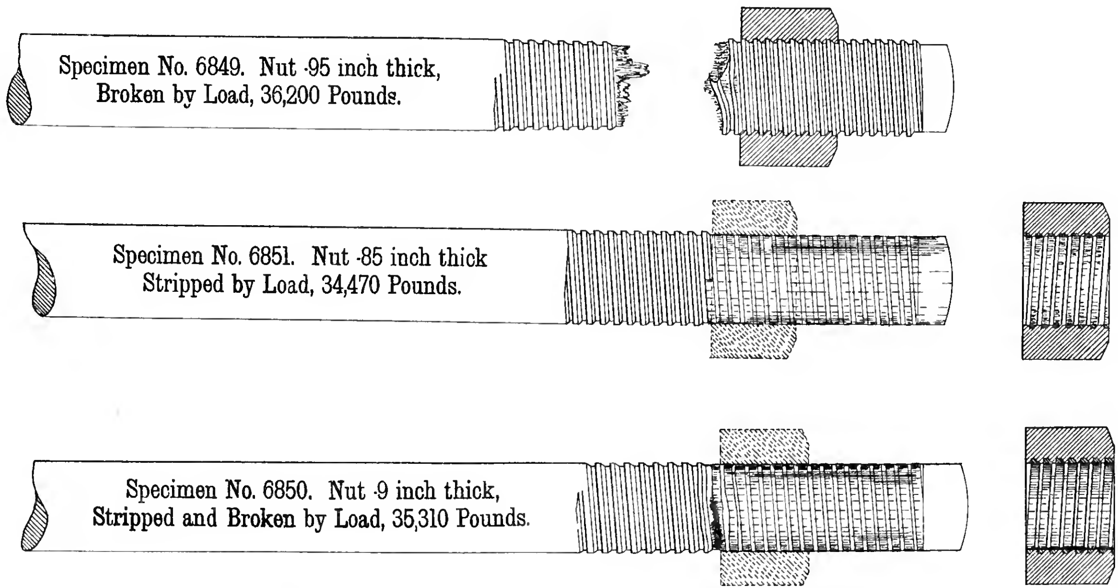
DIAGRAM:

Showing a Single Thread in a nut and on a bolt on all sizes from ½ inch to 6 inches in Diameter.



Used in the New System of Screw Threads, by John L. Gill, Jr.

JUNE, 1887.



Experiments with New Thread by John L. Gill, Jr., October, 1887.

I soon observed that my experimental thread had the same objections that existed in the Sellers form of thread, namely, that the altitude of the thread was dependent on the pitch or number of threads per inch, and was necessarily divisible by the fraction to the ten-thousandth of an inch, and that the strain was applied to a surface at an angle of 120° from the axis of the bolt, having a tendency to expand or burst the nut; so I abandoned further experiments in that direction.

At a meeting of the American Institute of Mining Engineers, held at Chattanooga, in 1885, Major Wm. R. King read a paper on the subject of screw-threads, in which he took the same ground that I did, that the ordinary thread was cut too deep into the iron, and consequently the bolt was weakened more than was necessary, and he proposed to remedy the evil, by increasing the number of threads per inch, thereby reducing the depth of the thread.

The experiments of which he gave an account were very interesting and sustained his views, but the plan he adopted has the same objections that the Sellers, the Whitworth and the V-threads have, namely, the unmeasurable altitude, and the objectionable angle of 55° or 60°, whereby the strain is applied at an angle of 120° to the axis, producing a tendency to wedge through the nut when being strained.

Major King stated in his paper, that when he used eighteen threads to the inch, the thread did not strip off, but that the bolt wedged through the nut.

This is certainly an argument against increasing the number of threads, or using any form of V-thread.

Fine threads have frequently been suggested, and your committee, in 1864, gave some consideration to the question, but the many objections urged against fine threads, induced the committee to reject them.

It would be impossible for any person to design a new form of thread, for the reason that every shape of thread that could be made has been used or described.

It occurred to me that a thread formed part square and part V (such as I had used for the pulling screw in building my testing machines, and such as is used in the construction of rolling-mill housings) might be applied to an interchangeable system, suitable for bridge work and car building.

I found that a thread might be made in this way in which the altitude was not dependent upon the pitch of the thread, and that I could make the altitude in proportion to the diameter of the bolt. I further discovered that making the altitude $\frac{1}{100}$ of an inch high, for each one-fourth of an inch in diameter, would reduce the cross-section of the bolt uniformly 15·35 per cent. on all sizes, so I worked out a table of sizes from one-half inch to six inches in diameter, without reference to the pitch of the threads, and then made a diagram to determine the pitch and the angle of the receding side. It will be observed that I use the same number of threads on the smaller sizes as the Sellers, but on some sizes I use a different number.

The Sellers system has nine fractional numbers, while mine has but one. As the lathes of this country are arranged for chasing threads from one to the inch and upwards, it is desirable to avoid fractional threads.

I make the resisting side of the thread at 90° to the axis, and the receding side at an angle of 45°, the top and bottom of the threads parallel to the axis of the bolt. The flat surface is found by subtracting the altitude from the pitch, and dividing the remainder by two.

I may say here that your committee of 1864 mentioned a thread having one side at a right angle to the axis and the other side at some other angle, and stated that it would be much the strongest form of thread, but they would not recommend it because it was only applicable to bolts in which the strain was applied in one direction only.

I would ask if any one can tell me of a bolt in which the strain is applied in more than one direction? Of course, feed screws to lathes and planers and the adjusting screws of fine mechanical apparatus have to be made to work either way, but in those cases special screws are usually made.

It will be observed, on examining the table, that my system reduces the cross-section of the bolt uniformly about 15·35 per cent., while the Sellers system reduces it eighteen per cent., on a six-inch bolt, and thirty-five per cent. on a half-inch bolt, with varying proportions on the intermediate sizes; the V-thread reduces a six-inch bolt twenty-four per cent., and varying reductions on sizes down to one-half inch, at which it reaches fifty-eight

per cent. Now, if the thread on a six-inch bolt is strong enough with a reduction of eighteen per cent., why waste material by cutting away from fifteen to thirty per cent. more?

I determined to make some tests to prove my figures before I brought the table before the public. Through the courtesy of Messrs. Hoopes & Townsend, who furnished the iron and nuts for the specimens, Mr. H. R. Heyl who furnished the machine shop labor in preparing the specimens, and of Mr. Grant (who has charge of the Fairbanks testing machine) and Mr. Tinius Olsen (the manufacturer of the Olsen testing machines), who separately made the tests for me, I am prepared to present you with the results, and also to lay the specimens before you for examination.

You will observe that the iron was of a very good quality, having a breaking strength of over 53,000 pounds per square inch, with an elastic limit of from sixty-three to sixty-eight per cent. of the breaking load. It was very ductile, as is shown by the elongations averaging over twenty-one per cent. in ten inches.

Some of my hearers not familiar with the testing of iron, may be a little surprised to see so much difference in the resisting strength of the different specimens made from the same lot of material, and of the same size. These differences are not greater than are found in the best of bar iron. The differences are not so great in steel, owing to its greater homogeneity.

The nuts were from common stock and were excellent, as not one of them showed any tendency to give way in the thread.

You will notice by the table that I used six specimens of each size, one-half inch, three-fourths inch and one inch, all twenty inches long, to determine the quality of the iron.

Six specimens each size one-half inch, three-fourths inch and one inch, having the Sellers thread, and six specimens each size, one-half inch, three-fourths inch and one inch having my new thread.

The results are clearly shown forth in Tables I and II. Table III presents the results of some experiments made to determine the stripping strength of the threads, and also the strength of the nuts.

There has been a general impression that nuts the thickness of half the diameter of the bolt, would break the bolt, but I found no one that could tell me how thin a nut would have to be, before the

thread would strip, so I made these experiments to determine this question. You will see that on a one-inch bolt having the Sellers thread, a nut the thickness of four-tenths of the diameter was as likely to strip the thread on the bolt as to break the bolt.

The thread will never strip in the nut, if of a good quality, as the strain is applied across the fibre of the iron, while on the bolt it is applied lengthwise of the fibre, and the circumference at the bottom of the thread on the bolt, is much less than the circumference of the thread at the base inside of the nut.

On my bolt a nut is required to be as thick as nine-tenths of the diameter, as was shown by the experiments. At that thickness of the nut, the bolt both broke and stripped, while at ·95 the bolt broke, and at ·85 the thread stripped; so if the nuts are made of the same thickness of the diameter of the bolt, there will be a margin of eleven per cent. in favor of the bolt breaking instead of stripping.

It is apparent, from these trials, that I utilize ninety per cent. of the strength of the nut by my proportions, while the Sellers form utilizes only forty per cent. of the nut.

ANALYSIS OF TABLES 1 AND 2.

Diameter of bolts,	½ in.	¾ in.	1 in.
Area of cross-section at base of thread,	·1662	·3739	·66476
Breaking load of specimens,	10,796	23,600	42,142
Breaking load of iron, per sq. inch,	54,998	53,418	53,657
Elastic limit of iron,	6,946	12,260	26,829
Elastic limit per cent. of breaking load,	64·33 p.c.	68·89 p.c.	63·66 p.c.
Gill thread reduces cross-section of bolt by calculation in table,	15·35 p.c.	15·36 p.c.	15·35 p.c.
By actual test, by breaking load,	11·45 p.c.	13·26 p.c.	11·95 p.c.
Sellers thread reduces cross-section of bolt by calculation in table,	35·71 p.c.	31·66 p.c.	29·84 p.c.
By actual test, by breaking load,	30·16 p.c.	29·04 p.c.	30·21 p.c.
Strength of Gill bolt by calculation in pounds with iron of above strength,	9,140	19,973	35,669
By actual test,	9,560	20,471	38,142

A NEW SYSTEM OF SCREW THREADS, BY JOHN L. GILL, JR.

PHILADELPHIA, PA., JUNE 1, 1887.

		½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4½ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
1	Diameter of bolt,	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4½ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
2	Number of threads per inch,	12·	11·	10·	9·	8·	7·	7	6·	6·	5·	5·	4·	4·	4·	4·	3·	3·	3·	3·	2½·	2½·	2½·	2½·	2·	2·	2·
3	Pitch of threads,	·083	·091	·10	·111	·125	·143	·143	·167	·167	·2	·2	·25	·25	·25	·25	·333	·333	·333	·333	·4	·4	·4	·4	·5	·5	·5
4	Altitude of thread,	[illegible]	·025	·03	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
5	Width of flat top,	·032	·033	·035	·038	·043	·49	·047	·054	·049	·06	·055	·075	·07	·065	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
6	Diameter of bolt at base of thread,	·46	·575	·69	·805	·92	1·035	1·15	1·38	1·61	1·84	2·07	2·30	2·53	2·76	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52

A TABLE SHOWING THE PROPORTIONS OF SCREW THREADS OF THE V, THE FRANKLIN INSTITUTE AND A NEW SYSTEM PROPOSED, BY JOHN L. GILL, JR., WITH THEIR COMPARATIVE STRENGTHS AND VALUES.

		½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
1	Diameter of bolt,	½ in.	⅝ in.	¾ in.	⅞ in.	1 in.	1⅛ in.	1¼ in.	1½ in.	1¾ in.	2 in.	2¼ in.	2½ in.	2¾ in.	3 in.	3¼ in.	3½ in.	3¾ in.	4 in.	4¼ in.	4½ in.	4¾ in.	5 in.	5¼ in.	5½ in.	5¾ in.	6 in.
2	Number of threads per inch, V and FRANKLIN INSTITUTE threads,	13·	11·	10	9·	8·	7·	7	6·	5·	4½·	4½·	4	4·	3½·	3½·	3¼·	3·	3·	2⅞·	2¾·	2⅝·	2½·	2½·	2⅜·	2⅜·	2¼·
3	Number of threads per inch, Gill thread,	12·	11·	[illegible]	9·	8·	7·	7·	6·	6·	5	5·	4·	4·	4	4	3·	3·	3·	3·	2½·	2½·	2½·	2½·	2·	2·	2·
4	Altitude of V thread,	·0666	·0780	·0566	·0960	·1082	·1236	·1236	·1444	·1732	·1924	·1924	·2165	·2165	·2474	·2474	·2665	·2886	·2886	·3012	·3149	·3299	·3464	·3464	·3646	·3646	·3848
5	Altitude of FRANKLIN INSTITUTE thread,	·0500	·0569	[illegible]	·0720	·0812	·0927	·0927	·1083	·1299	·1443	·1443	·1624	·1624	·1856	·1856	·1999	·2165	·2165	·2259	·2361	·2474	·2598	·2598	·2735	·2735	·2886
6	Altitude of Gill thread,	·02	·025	[illegible]	·035	·04	·045	·05	·06	·07	·08	·09	·10	·11	·12	·13	·14	·15	·16	·17	·18	·19	·20	·21	·22	·23	·24
7	Width of flat top of FRANKLIN INSTITUTE thread,	·0096	·0113	·0125	·0140	·0156	·018	·0180	·0210	·0250	·0280	·0280	·0310	·0310	·0357	·0357	·0384	·0410	·0410	·0435	·046	·048	·05	·05	·0526	·0526	·0555
8	Width of flat top of Gill thread,	·032	·033	[illegible]	·038	·043	·049	·047	·054	·049	·06	·055	·075	·07	·065	·06	·097	·092	·087	·082	·11	·105	·10	·095	·14	·135	·13
9	Diameter of bolt, full section,	·5	·625	·75	·875	1·	1·1250	1·25	1·50	1·75	2·	2·25	2·5	2·75	3·	3·25	3·5	3·75	4·	4·25	4·50	4·75	5·	5·25	5·50	5·75	6·
10	Diameter of bolt at base of V thread,	·3668	·4677	·5757	·683	·7836	·8778	1·0028	1·2112	1·4036	1·6152	1·8652	2·0673	2·3170	2·5052	2·7552	2·9670	3·1728	3·4428	3·6476	3·8702	4·0902	4·3072	4·5572	4·7708	5·0208	5·2304
11	Diameter of bolt at base of FRANKLIN INSTITUTE thread,	·3993	·5072	[illegible]	·7310	·8376	·9396	1·0666	1·2834	1·4902	1·7114	1·9614	2·1752	2·4252	2·6288	2·8788	3·1002	3·3170	3·567	3·7982	4·0278	4·2552	4·4804	4·7304	4·9530	5·2030	5·4228
12	Diameter of bolt at base of Gill thread,	·46	·575	·69	·805	·92	1·035	1·15	1·38	1·61	1·84	2·07	2·30	2·53	2·76	2·99	3·22	3·45	3·68	3·91	4·14	4·37	4·60	4·83	5·06	5·29	5·52
13	Area of cross section, original size,	·1963	·3068	·4418	·6013	·78539	·9940	1·2271	1·7671	2·4052	3·1416	3·9761	4·9080	5·9396	7·0686	8·2939	9·6211	11·044	12·566	14·186	15·904	17·720	19·635	21·648	23·758	25·967	28·271
14	Area of cross section at base of V thread,	·1056	·1711	[illegible]	·3664	·4822	·6052	·7901	1·152	1·548	2·048	2·732	3·355	4·216	4·928	5·961	6·914	7·907	9·214	10·452	11·760	13·140	14·570	16·310	17·880	19·800	[illegible]
15	Area of cross section at base of FRANKLIN INSTITUTE thread,	·1262	·2429	[illegible]	·4197	·5510	·6934	·7908	1·2956	1·7441	2·3003	3·0215	3·7161	4·6194	5·4272	6·5070	7·5486	8·6414	9·9870	11·330	12·742	14·286	15·766	17·575	19·271	21·261	[illegible]
16	Area of cross section at base of Gill thread,	·1662	·2507	[illegible]	·5089	·66476	·8413	1·0357	1·4957	2·036	2·659	3·3634	4·1547	5·0273	5·9827	7·0220	8·1433	9·3482	10·636	12·010	13·461	15·000	16·6192	18·322	20·109	21·979	[illegible]
17	Per cent. reduction of cross section for V thread,	58·19	44·23	[illegible]	38·97	38·63	39·11	35·60	34·81	35·72	34·65	31·28	31·64	28·98	30·98	28·13	28·14	28·40	26·79	26·33	26·05	25·84	25·79	24·65	24·74	23·75	[illegible]
18	Per cent. reduction of cross section for FRANKLIN INSTITUTE thread,	35·71	30·61	31·66	30·20	29·84	30·24	27·40	26·71	27·52	26·71	23·07	24·25	22·20	23·26	21·58	21·55	21·63	20·52	20·09	19·93	19·75	19·73	18·83	18·76	18·12	[illegible]
19	Per cent. reduction of cross section for Gill thread,	15·35	15·35	15·36	15·36	15·35	15·36	15·35	15·36	15·35	15·36	15·36	15·35	15·36	15·35	15·36	15·36	15·35	15·35	15·36	15·36	15·35	15·36	15·36	15·36	15·35	[illegible]
20	FRANKLIN INSTITUTE bolt, per cent. stronger than V,	19·50	18·58	[illegible]	14·54	14·27	14·57	12·73	12·41	12·59	12·40	10·65	10·76	9·55	10·06	9·12	9·46	9·28	8·52	8·42	8·25	8·22	8·16	7·72	7·77	7·37	[illegible]
21	Gill bolt, per cent. stronger than FRANKLIN INSTITUTE,	31·69	24·06	[illegible]	21·46	20·64	21·33	16·52	15·44	16·81	15·50	11·31	11·81	8·83	10·30	8·04	7·88	8·18	6·43	6·00	5·73	5·48	5·45	4·27	4·30	3·38	[illegible]
22	Gill bolt, per cent. stronger than V,	57·38	51·79	[illegible]	39·13	37·86	39·01	31·37	29·77	31·52	29·83	19·51	23·84	19·23	21·40	17·78	17·77	18·22	15·50	14·91	14·45	14·15	14·07	12·32	12·47	11·01	[illegible]

RECORD OF TESTS MADE BY MR. GRANT AND TINIUS OLSEN, TO SHOW THE DIFFERENCE BETWEEN THE GILL AND SELLERS FORM OF SCREW-THREADS.

TABLE I.—*To Determine the Quality of the Iron.*

A.—½″ ROUND IRON.

By whom made.	Laboratory Number	Breaking Load in Pounds.	Elastic Limit in Pounds	Elongation in 10 Inches
G	6865	11,100	6,850	2·08
G	6942	10,645	6,400	2·02
G	6943	10,630	6,300	2·09
O	5808	10,800	7,160	2·12
O	5837	10,725	7,525	2·14
O	5838	10,875	7,5[illegible]	2·13
Average, . . . Per square inch,		10,796 54,998	6,946	2·14

D.—¾″ ROUND IRON.

By whom made.	Laboratory Number	Breaking Load in Pounds.	Elastic Limit in Pounds	Elongation in 10 Inches
G	6860	23,470	16,800	2·52
O	5801	23,910	14,860	2·50
G	6934	23,260	16,750	2·50
G	6935	23,510	16,700	2·48
O	5829	23,730	16,250	2·41
O	5830	23,7[illegible]	1[illegible]	2·47
Average, . . . Per square inch,		23,600 53,418	16,260	2·48

G.—1″ ROUND IRON.

By whom made.	Laboratory Number.	Breaking Load in Pounds.	Elastic Limit in Pounds.	Elongation in 10 Inches.
Gill	5721	42,000	26,000	2·47
Grant	6846	42,565	26,500	2·50
G	6926	41,480	26,900	2·02
G	6927	42,090	27,300	2·04
O	5821	42,600	27,650	2·22
O	5822	42,120	26,625	2·17
Average, . . . Per square inch,		42,142 53,657	26,829	2·23

TABLE II.—*To Determine the Strength of the Bolts.*

B.—½″ BOLTS.

By whom made.	Laboratory Number.	Gill Thread. Breaking Load in Pounds.	Sellers Thread. Breaking Load in Pounds	Elongation in 10″. Gill Thread.	Elongation in 10″. Sellers Thread
O	5809	9,975		·78	
G	6944		7,505		0
O	5810	9,300		61	
G	6945		7,590		·0
G	6949	9,460		·69	
G	6946		7,410		0
O	5842	9,4[illegible]		·7[illegible]	
O	5839		7,225		0
O	5843	9,925		67	
O	5840		7,630		·0
O	5844	9,250		·65	
O	5841		7,880		0
Average, . . .		9,560	7,540	·68	·0

E.—¾″ BOLTS.

By whom made.	Laboratory Number.	Gill Thread. Breaking Load.	Sellers Thread. Breaking Load.	Elongation in 10″. Gill Thread	Elongation in 10″. Sellers Thread.
G	6939	19,945		55	
G	6936		16,690		23
G	6940	20,590		·54	
G	6937		16,140		·10
G	6941	20,330		·45	
G	6938		16,350		·11
O	5834	(Stripped) ([illegible])		[illegible]	
O	5831		16,520		·03
O	5835	20,580		55	
O	5832		16,875		·00
O	5836	20,525		·55	
O	5833		17,910		·28
Average, . . .		20,471	16,747	·54	·12

H.—1″ BOLTS.

By whom made.	Laboratory Number.	Gill Thread. Breaking Load.	Sellers Thread. Breaking Load.	Elongation in 10″. Gill Thread.	Elongation in 10″. Sellers Thread
G	6931	36,270		72	
G	6928		29,010		·30
G	6932	38,375		80	
G	6929		28,310		·27
G	6933	38,820		·83	
G	6930		29,000		·32
O	[illegible]	[illegible]		·80	
O	5823		30,150		·32
O	5827	38,740		·75	
O	5824		31,250		·36
O	5828	37,900		·67	
O	5825		28,750		·28
Average, . . .		38,14[illegible]	29,411	·76	·31

TABLE III.—*To Determine the Stripping Strength.*

C.—½″ BOLTS

By whom made.	Laboratory Number		Thickness of Nut in Inches.	Thickness per Cent. of Diameter.	Destructive Load in Pounds.	Elongation in 10 Inches.	Remarks.
O	5809	Gill Thread	·483	96·6	9,975	·78	Broke.
G	6949	Gill Thread	·47	94·	9,460	·57	Stripped
G	6948	Gill Thread	·46	92·	8,085	·46	Broke
G	6947	Gill Thread	·454	91·	8,889	·45	S. and B
O	5810	Gill Thread	·45	90·	9,300	·61	Broke.
O	5811	Gill Thread	·40	80	8,940	·59	Stripped
O	5812	Gill Thread	·35	70·	9,225	·55	"
O	5813	Gill Thread	·30	60·	8,510	·48	"
G	6866	Sellers Thread.	·3	60·	7,570	·0	Broke.
G	6867	Sellers Thread.	·25	50	7,055	·0	Stripped
G	6868	Sellers Thread.	·2	40·	6,575	·0	"

F.—¾″ BOLTS

By whom made	Laboratory Number		Thickness of Nut in Inches.	Thickness per Cent. of Diameter.	Destructive Load in Pounds.	Elongation in 10 Inches.	Remarks.
O	5803	Gill Thread	75	100·	20,700	·78	Broke
O	5804	Gill Thread	·7	93·	20,650	·76	S. and B.
O	5805	Gill Thread	·65	86·	21,190	·6	Stripped.
O	5806	Gill Thread	·6	80	20,425	·5	"
O	5807	Gill Thread	·55	73·	21,395	·65	"
G	6861	Sellers Thread	·4	53·3	16,880	·1	Broke
G	6862	Sellers Thread	·35	46·6	16,635	·02	"
G	6863	Sellers Thread	·3	40·	15,095	·0	Stripped.
G	6864	Sellers Thread	·25	33·3	12,985	·0	"

I.—1″ BOLTS.

By whom made.	Laboratory Number.		Thickness of Nut in Inches	Thickness per Cent. of Diameter.	Destructive Load in Pounds.		Remarks
G	6843	Iron.			39,530	2·65	50·241 per □ inch
"	6849	Gill Thread	·95	95	36,200	·8	Broke.
"	6850	Gill Thread	·9	·90	35,310	·67	S. and B.
"	6851	Gill Thread	·85	·85	34,470	·6	Stripped.
"	6871	Gill Thread	·8	·80	35,390	·6	"
"	6872	Gill Thread	·75	75	36,070	·76	"
Gill	5720	Gill Thread	·8	·80	32,800	—	"
"	6855	Sellers Thread	·5	50	30,305	·3	Broke
"	6856	Sellers Thread	·475	·475	29,005	·28	"
"	6857	Sellers Thread	·45	·45	28,390	·39	"
"	6858	Sellers Thread	·4	·40	26,945	·27	S. and B.
"	6859	Sellers Thread	·35	·35	25,670	·13	Stripped

Strength of Sellers bolt by calculation in pounds with iron of above strength, ...	6,940	16,126	29,595
By actual test, ...	7,540	16,747	29,411
Gill bolt stronger than Sellers—			
Per cent. by calculation in table, ...	31·69 p.c.	23·84 p.c.	20·63 p.c.
Per cent. stronger by actual test, by breaking load, . .	26·79 p.c.	22·24 p.c.	29·69 p.c.

EXPLANATION OF TABLES.

G stands for Grant and O for Olsen. The iron for the specimens in the Tables I, II and III, letters A, B and C, were all taken from the same bundle.

The iron used in Tables I, II and III, letters D, E and F, were all taken from the same bundle.

The iron used in Tables I and II, letters G and H, were from the same bundle, while the iron in Table III, letter I, was from another lot, at a different time, but from the same mill as the other specimens.

It was of lower tensile strength, being only 50,241 pounds per square inch, while the iron in Tables G and H averaged 53,657 pounds, its elastic limit for the specimen No. 6,848, was 25,400 pounds, while the average of the others was 26,829 pounds. The elongation in ten inches being 2·67 inches, was greater than the average of the other specimens, which was 2·23 inches in the same length. Its greater ductility is apparent.

TABLE I.

Six specimens of iron, each size one-half inch, three-fourths inch and one inch were used to test the quality of the iron.

The average strength, elastic limit, and elongation in ten inches is shown at the foot of each column.

TABLE II.

Six specimens each size one-half inch, three-fourths inch and one inch having the Gill thread; and six each size one-half inch, three-fourths inch and one inch are shown, having the Sellers thread. The columns showing the Gill threads are placed in juxtaposition with the columns showing the Sellers thread, so that an easy comparison can be made, and a correct idea formed of the comparative strength of bolts, having the different forms of threads on them.

The nuts used in this table were taken from common stock, and are supposed to be in thickness the same as the diameter of the respective sizes of bolts. The nuts were not measured. Specimen No. 5,834, letter E, stripped with a load greater than was required to break any other specimen.

TABLE III.

The tests in this table were made to determine, if possible, the thickness of the nut that would be required to strip the threads instead of breaking the

bolts. The nuts were all turned down except specimen No. 5,803, shown in letter F, which was left full thickness, and placed in this table to show that one broke the bolt at a lower load than was required to strip the threads on several other specimens.

On examining Table III, it will be seen that bolts having the Sellers thread, stripped with nuts the thickness of fifty per cent. of the diameter on the one-half inch size, while on bolts three-fourths inch and one inch in diameter, stripped with nuts reduced to forty per cent. of their diameter in thickness. There was no elongation in the one-half-inch specimens, and one-tenth of one per cent. in one specimen of three-fourths inch size, and two one-hundredths in another. The one-inch specimens all showed some elongation.

The bolts having the Gill thread, in this table, showed some curious features. In Section C, one-half-inch size, a specimen with nut ·46 of an inch thick, being ninety-two per cent. of the diameter, broke at a lower load than any other specimen. Another specimen with a nut ·35 of an inch thick, being only seventy per cent. of the diameter, stripped with a load nearly equal to the average breaking load of that size.

Examining Section F, it will be seen that two specimens having nuts ·55 and ·65 of an inch thick, being respectively seventy-three per cent. and eighty-six per cent. of the diameters, stripped with a greater load than was required to break any other specimen of the same size. The iron in Section I being more ductile and of lower tensile strength than that in Sections G and H, comparisons cannot be made with each other.

In Section I, it will be observed that a bolt with a nut ·90 per cent. of the diameter, with the Gill thread, both broke and stripped; that all bolts with nuts over ·90 per cent. of the diameter thick broke, while all bolts with nuts under this thickness stripped.

One specimen with a nut ·75 of an inch thick, stripped with a load nearly equal to that required to break the strongest bolt in this series of tests.

EXPLANATION OF PLATES.

PLATE I.

Is a chart showing the shape and relative proportions of the various forms of threads, representing the thread on a bolt one inch in diameter with eight threads to the inch.

PLATE 2.

Represents sections of bolts, with the different forms of threads having nuts in place.

PLATE 3.

Is a diagram showing the relative proportions of a single thread of the Gill form. The outside lines, forming a trapezoid at the right-hand side of the diagonal line, represent the thread on a six-inch bolt. The small trapezoid in the centre of the diagram represents the thread on a bolt one-half inch in diameter. The other trapezoids represent the threads on the varying sizes between.

The top line of each trapezoid represents the flat face at the top of the thread, the vertical lines, the altitude and resisting side of the hread. The bottom lines of the full parallelogram represent the pitch of the threads, and the diagonal line the receding side of the thread.

This diagram shows the uniform increase of one-hundredth of an inch for each one-quarter of an inch increase in diameter of bolt.

PLATE 4.

Represents three specimens described in Table 3, letter *I*. Specimen No. 6,849, with a nut the thickness of ninety-five per cent. of the diameter of the bolt, and broken by a load of 36,200 pounds.

Specimen No. 6,850 with nut ninety per cent. of the diameter in thickness broken and stripped by a load of 35,310 pounds, and specimen No. 6,851, with nut eighty-five per cent. of the diameter in thickness stripped by a load of 34,470 pounds.

HEATING CITIES BY STEAM.

BY CHARLES E. EMERY, PH.D.

[*A Lecture Delivered before the* FRANKLIN INSTITUTE, *Friday, November 18, 1887.*]

THE LECTURER was introduced by Vice-President MR. FRED. GRAFF, and spoke as follows:

Members of the INSTITUTE, *Ladies and Gentlemen:*

The advantages of a steam supply from a central station for the buildings in a city or village, and even for the detached buildings of hospitals and other public institutions in a park, are very evident, and such a system has, in the past, been many times suggested as desirable. About fifteen years ago, Birdsall Holly, of Lockport, N. Y., made experiments in his yard to show the loss of heat in transmitting steam through an underground conductor, the outcome of which was the design of a practical system adapted for street distribution, in which stuffing boxes were arranged at regular intervals of about 100 feet, and anchored fast, so as preserve their location and permit the sliding sleeves to move in and out freely, in line. Outlets were also provided in chambers back of the stuffing boxes for the attachment of service pipes to distribute the steam to buildings, so the supply was from stationary points the same as if boilers were located at such points. Simple as these improvements seem to have been, compared with previous

arrangements of interior steam piping, they form an important element of the success of modern systems of steam distribution in cities. The large steam plant of the New York Steam Company has been built up, under the direction of the writer, on the principle in the Holly patents, above described, but without the use of one of the Holly details, and the steam from boilers of 12,000 horse-power is now being delivered at a pressure of eighty pounds and upwards for power, as well as heat, through some five miles of large steam pipes, some of which extend three-fourths of a mile from the boiler station.

It is proposed to discuss the general features of what is technically called a District Steam System, and to introduce, in connection therewith, brief descriptions of the work of the New York Steam Company, illustrated by drawings of the principal details used.

A district steam plant is in some respects similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of underground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that consumers can be accommodated when and where desired, involve many more difficulties and require many modifications in detail, compared with a system where all the property is under one control, where space underground is rarely obstructed or valuable, and where the whole plant, with all its ramifications, may be laid out before the work is commenced.

The nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and in some respects an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

Dry or saturated steam is well adapted for transmission to a distance, for the simple reason that the temperature always corresponds to the pressure. The laws of thermodynamics show that absolute temperatures and pressures always bear a constant relation. It follows, therefore, that steam of a given pressure is as valuable at the distance of a mile or more from the boiler in which it is generated, as it is at the boiler itself; also that steam mixed with water, has, when the water is removed,. all the properties, and is equally valuable as any other steam of the same pressure. In short, steam does not *deteriorate* the least in transmission, so long as it is steam; that is, has been freed of the water of condensation incident to its transmission. Pressure may be lost, but permit me to repeat, that the steam is as valuable as any steam of the same pressure. The problem of separating steam from water is well understood. Evidently if a mixture of steam and water be passed through a drum as large as the steam space of the boiler in which the same quantity of steam would ordinarily be generated, the water will be separated by gravity, the same as in the boiler itself. In most cases the pipes themselves act as drums. In any case, by a proper application of principles, it is possible to transmit steam to as great distances as any other fluid. The actual maximum distance must be governed by commercial considerations as to relative cost of piping and stations. To make steam efficient then, it is necessary only to maintain the desired pressure at the ends of the lines, and this depends upon the size of the pipes and the loss of pressure that can be permitted.

The first problem in designing a steam plant is to ascertain the total quantity of steam required and the quantity necessary to supply in detail the several blocks on each of the streets through which the pipes are to be run. In New York this was approximately obtained, first, by collecting the statistics on file in the Police Department, with relation to the steam boilers in place in the city, rules being given the computers by which the approximate power of a boiler could be determined from the external dimensions and type, which were the only dimensions taken by the boiler inspectors and reported to the Police Department. The aggregate cubic capacity of all the buildings within the areas

which it was expected to heat were also computed approximately from the insurance maps, and this multiplied by a proper factor gave the estimated quantity of steam required to heat that space. This preliminary work, although simple in its character, involved a great deal of labor, on account of the number of streets, buildings and boilers to be considered.

The first station of the company was located on Greenwich Street, between Dey and Cortlandt Streets. The building was designed to contain 16,000 horse-power of boilers of the Babcock and Wilcox type, and will be illustrated and explained hereafter.

In all, properties were purchased for ten stations in different parts of the city, but of these but two have as yet been constructed, viz., the one mentioned at Cortlandt and Greenwich Streets, designated as Station "B," and an inside or temporary one at Fifty-eighth Street and Madison Avenue.

Some idea of the magnitude of the work can be obtained from the statement that there are already in position in the first station one sixteen-inch pipe, one fifteen-inch pipe and one eleven-inch pipe, with only part of the capacity of the building yet utilized, and that it expected to put in in addition one thirty-inch pipe to keep up the pressure at a distance as the demand increases.

Considerable investigation was made to ascertain the proper formula for determining the sizes of pipes required to transmit the steam. The difficulty was not so much in finding formula as to decide which were best applicable. As is generally the case, the simplest was finally determined upon, based directly upon the laws of falling bodies, and in form, that generally used for the flow of water in pipes, simply substituting for the density of water that of steam at the pressure to be carried. Most of the experiments on the flow of gaseous fluids given in the text-books refer to air at low pressures and with very small quantities of discharge. There were, however, some experiments on the flow of compressed air in the pipes supplying the drills in the Mont Cenis Tunnel, where the pressure and quantity of air moved were sufficient to compare favorably with the conditions under which steam was to be transmitted. By substituting numerical values determined from these experiments in the ordinary water formula with a character representing the density introduced, a general formula was obtained in which the constant very curiously and satisfactorily coincided very

closely with those given by Wiesbach, in relation to the flow of air at about the same velocity as was expected in the steam pipes. It should be observed that the loss of pressure due to transmission varies also with the density of steam, so that any formula founded on a constant density is not precisely correct. As, however, the loss of pressure was to be restricted to ten pounds, the original formulæ were based on the average density. At a later date, however, investigations were made in which the variations in pressure were taken into consideration; the formula derived from the water formula being considered a differential formula with relation to the flow of steam. By this means a formula was obtained which, it was believed, well represented the probable facts for all steam pressures, and all losses of pressure in transmission. Between the limits of pressure it was expected to use in practice, it was found that practically one formula was as exact as the other, so the use of the simpler one was continued for general use. When the slope was introduced in the formula, to wit, ten pounds per one-half mile, and the density which was first fixed at that due to seventy pounds, with the expectation of going from seventy-five pounds down to sixty-five, the formula for the weight of steam discharged per hour reduced at once to

$$W = 87{\cdot}3\, d^{\frac{5}{2}};$$

d, being the inside diameter of pipe in inches.

This form results from the fact that the areas of the pipes vary as the squares of their diameters, and the hydraulic mean depths which are proportioned to the friction as the square roots of the diameters, so the products of the two vary as the $\frac{5}{2}$ power. For strict accuracy some modifications should have been introduced in the formula, as the friction undoubtedly reduces as the velocity increases, and it is probable also that the friction reduces faster than the hydraulic mean depth. It was not necessary to consider these points, however, as the variation in velocity and density were so small. In practice it was not found expedient to reduce the pipes as rapidly as the mere conditions of demand, according to the maps above referred to, would indicate. It was thought that possibly there might be a concentration of demand on certain lines, and it was also desirable to make provision f r reinforcing the pipes near their ends from other

stations should it become necessary. Consequently, in practice, only the lines leading to the boiler house were proportioned by the rule, and the others as a general thing were made larger. It was not thought best in the down-town streets to lay any steam pipe less than six inches in diameter throughout the length of a long block, and although this was small by calculation for some blocks, still as it could be fed at both ends, it was considered sufficient, and has since so proved in practice. The above formula was designed to carry the whole capacity of the pipe to its end, whereas in practice steam is being continually drawn off, thereby enabling the remaining quantities of steam to be carried along with less relative reduction of pressure. On the whole, therefore, considering the various conditions, it was decided to increase the value of the constant in the formula to an even 100, and the table of the carrying capacity of pipes now used is simply derived by raising the actual internal diameter of the various nominal sizes of pipe in inches to the $\frac{5}{2}$ power, and carrying the decimal point two places to the right.

It is found in practice that steam pipes can be so protected that the loss of condensation will be a very small proportion of their carrying capacity. Experiments were made before the plant of the New York Steam Company was built, which showed that mineral wool, of ordinary quality, furnished very nearly the same resistance to the passage of heat as the same thickness of hair felt, and that the better qualities were equal or even superior in this respect to hair felt. As mineral wool is non-combustible, quite permanent when kept dry and not subject to friction, and withal could be manufactured quite cheaply, it was fixed upon as the material to insulate the pipes of the New York Steam Company. In a majority of cases the pipes were suitably supported in the bottom of a trench, brick walls built up at either side, and covered with planking and roofing material, as will be illustrated hereafter, so as to leave a space of from three to four inches about the pipe on all sides, in which mineral wool was placed in bulk. In some cases the wool was placed inside of wood casing of pump logs, but this was not considered a part of the regular system, and has not proved as desirable or durable as the other plan. The result of this method of covering has been that with nearly five miles of large pipes, also about two miles of smaller pipes used as

services, all under steam continuously, days, nights and Sundays, there was required but 150 horse-power each of thirty pounds of water per hour, to supply the condensation in the mains. The mains vary from sixteen inches in diameter to six inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam. The water of condensation, however, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocities in a large pipe, graded so as to have a slight descent *away from* the source of supply, the water in the steam would separate by gravity, and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the stream from the top of such a pipe and arranging to blow out the water at intervals from the bottom, the length of the pipe could be continued indefinitely, no inconvenience would result, except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is, to a greater or less extent, entrained by the current of steam. This is particularly the case when the steam is moving at a high velocity. In practice the up grades, in the direction the steam is transmitted, are made as sharp and as short as possible, and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long. This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases, arrangements are made to trap out the water of condensation at the bottom of every dip of the pipes, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water is removed automatically by a steam trap, and returned to the boiler house through another system of pipes, called return water pipes, the

details of which, as well as of the traps, will be referred to hereafter.

The expansion of small pipes is generally provided for by means of bends and offsets, which will spring sufficiently. This method, in its simpler form, is applicable to short lengths only, but if the arrangement be well studied, pipes of any length may be laid on this system. For instance, if it be desired to run a pipe from one end of a long building to another, it may be accomplished by crossing and recrossing a sufficient number of times. No known rules for this kind of work are formulated. The workman is supposed to make the offsets of such a number and with such lateral lengths that expansion will not strain the joints. Frequently, however, insufficient attention is given to this matter, and leaks are developed at important fittings, which it seems impossible to keep in repair, and the work can only be made satisfactory by changing the system to suit the actual conditions. A modification of the offset system with what are called swinging elbows forms a much safer method of providing for expansion, but is less used, as more fittings are required, and some little study is necessary to adopt the work to the straight lines and flat grades necessary in a building. It is, however, a very desirable way of laying long pipes of limited size underground and elsewhere, where the grade can be changed as required.

Swinging elbows are also used to pass obstructions, such as cross pipes, which can be inclosed in a yoke in the steam pipe. The steam takes the upper part of the yoke, the water of condensation the lower, and drainage is not interfered with.

Stuffing boxes or slip joints are frequently used on long lengths of pipe to provide for expansion, though generally on large pipes only. This system answers very well for water pipes, or where the steam pressure is low. With high pressures, the packing has to be very compact to resist the pressure, and great care and some considerable expense are required to keep the stuffing boxes in order and prevent them from leaking. Frequently stuffing boxes are applied without due care in anchoring the pipe. Cases have occurred where pipes were prevented from sliding simply by a lateral connection coming in contact with the side of an opening in a wall or partition. In laying a number of stuffing boxes on a length of pipe without anchorages, the whole pipe may shift to

the box which is loosest, and the others may not move at all until the first has a very extreme movement, or, as has sometimes happened, is pushed entirely in. Sometimes, in cooling such a system, the sleeve of one stuffing box is pulled entirely out of the packing.

The original street system of Birdsall Holly, who used anchored service stuffing boxes at frequent intervals, has already been referred to. The value of his system is best exemplified by briefly describing a modification of it used by a company in the city of New York, started in opposition to the work of the New York Steam Company, soon after the latter was well under way.

In the case referred to, stuffing boxes were used, but they were located only at the corners of the streets in castings, which also served as crosses to connect with the main street laterals. The consequence was that expansion had to take place for the whole length of the block, and this system was carried out whether the blocks were 100 feet long or 400 feet. The pipes were carried on rollers, so that they would move freely. If mere expansion and contraction had been all that was to be provided for, the system would have worked well enough, if properly constructed. In all cases, however, in street work, the grade and line must be changed at intervals to avoid obstructions. These were overcome in this particular case, even for pipes eight inches in diameter, by making rigid offsets, sometimes of several feet, with common screw elbows. The friction of the stuffing boxes was so great that leaks soon developed in the elbows of these offsets, and in one or two cases the elbows actually broke, letting the steam freely into the ground, and causing what were termed explosions. Moreover, the pipes, which were supposed to be nearly straight, did not always move freely in the stuffing boxes, from the great difficulty in setting the stuffing boxes exactly in line with the pipe. It was very difficult to keep the stuffing boxes tight, and the man-holes in which they were located were so hot that the men became exhausted in attempting to attend to the packing. In this system the services were taken from independent pipes anchored only at the street corners, and running for the length of the block, it being expected that there would be spring enough in the various laterals entering the house to allow for the expansion due to the length of half a block. As, however, some of the blocks were very long, it became necessary to leave considerable space in the boxing around the lat-

eral pipes, particularly near the centres of the blocks. During the early part of the work, when steam was turned on and off frequently, the fitters would sometimes allow for expansion one way and sometimes the other. They were at first accustomed to allow for a movement of the pipes from the nearest street corner as it was heated up. When the pipes were already heated, they thoughtlessly, at times, left the room on the same side, for which reason, when the pipe was shut off, the contraction would cause the service to strike the boxing, which produced leaks, and, in some cases, rupture.

In one case, where connections had been made when the pipe was heated, the service was sheared off as the pipe cooled off, which was not known until steam was again turned on, when the lampblack used for insulation was blown all over the building. In one case of this kind, a break occurred on shutting the pipe off, and in repairing the break, the fitter allowed for contraction instead of expansion, without noting that the pipe he connected to was then cold, and the same service pipe was broken a second time when the street pipe was again heated. The wisdom of Holly in arranging that the fitters should only have distances of half a hundred feet to provide for by offsets, instead of half a block, could not be more forcibly illustrated. It is almost needless to say that the system, in which the stuffing boxes were placed only at the street corners, proved an utter failure, and its operation was discontinued after a few months' trial.

When the speaker was called upon to design a steam system, it appeared to him very desirable to avoid the necessity of using slip joints, with their leaks and expense in care and attention, and it was readily seen that an elaborate system of offsets was not practicable. Experiments were, therefore, commenced with modifications of what are known as diaphragm joints, in which two annular discs of metal are bolted together through a separating ring at their outer edges, and the inner edges bolted to the ends of the lengths of pipe, or a single disc is bolted at the periphery to a large chamber connected with the pipe on one side, and the centre of the disc to the pipe on the other. With these joints, the elasticity of the disc permits limited expansion; the movement causing the discs to be dished one way or the other, as may be arranged. All these devices, when made as ordinarily proportioned, proved too stiff, and had too limited a range for use in a street system.

A trial was made with cast-iron pipe, cast very thin and corrugated very deeply, it being hoped that each pipe could be corrugated sufficiently safely to provide for the expansion of its own length. In such case it was proposed to put in a lining of thin iron to form a smooth passage for the steam. These experiments made it doubtful if the plan would succeed, even if the pipes were corrugated the entire length. Although the cast iron was elastic within a certain limit, the great difficulties in obtaining uniform thicknesses made breaks liable to occur unexpectedly. Experiments with several plates held at the inner and outer edges were more satisfactory, but as ordinarily proportioned were too stiff, and had too little range of movement for the purpose. If the discs were originally dished in one direction with a view of forcing them first flat and then to dish them in the other by pressure, they were, of course, very much stiffer. Improvements were made by reducing the thickness of the plates and corrugating them annularly, but even when the plates were made of soft steel corrugated annularly as aforesaid, and six inches free space left between the inner and outer flanges, the plates still proved too stiff, so that there was danger of breaking the joints on the pipes to move the expansion joints, and it was not thought practicable to use more than half an inch movement for each of such diaphragms. Diaphragms of this kind were actually dished from one-half inch in one direction to one-half inch in the other, making a movement of one inch, but some parts of the disc developed a tendency to stiffen sooner than the rest, and the movement could not be made back and forth a number of times without disturbing the symmetry of the disc. The improvement due to reducing the thickness was, however, so great that the suggestion came to mind that if the plates could be still further reduced with safety, the available deflection would be inversely as the cube of the thickness, and sufficient movement could be obtained.

A successful expansion joint was finally made by using discs of copper less than one-sixteenth inch thick (0·04 being finally settled upon), corrugated concentrically and supported on radial backing plates, which prevented the diaphragm from being distended, to rupture by the pressure.

Elaborate drawings of this device are shown upon the screen; one, called a double variator, having two diaphragms and providing for expansion from two fixed points on either side fifty feet away; the other, called a single variator, having but one diaphragm, and providing for expansion from one direction only. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, these plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it, by means of a special tool seen on the screen. The stems of the valves are extended to the surface of the street, and may be operated through suitable openings in castings placed between the paving stones. At regular intervals of about fifty feet the pipes are connected by means of ball joints, which enable the direction to be changed slightly and take out the strain. Both the ball and plain joint flanges are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface and become absolutely tight, even without the use of paint or putty. Pipes of six inches in diameter or less are screwed into the fittings. Larger pipes (and some have been used as large as sixteen inches in diameter) are rolled into the flanges and fittings with an expanding tool. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with boxes, which cover the connecting flanges and terminate in cylinders of metal, which are built in the brick work surrounding the variators. A number of illustrations are shown of the various crosses, tees, and other special fittings required, which are necessarily made of a substantial character to resist permanently the steam pressure of eighty pounds. The bodies of the crosses and tees are made globular, to better resist the strains to which they are subjected. Wherever a valve is placed in the pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges in the pipes, and masonry built against the castings with wings well spread out, to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains were run originally, one for steam, the other for the return water of condensation. Generally the latter main is laid lower than the other, so that

the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains, through what are called " drop crosses."

The traps used by the New York Steam Company are seen on the screen. They are of the bucket variety, with valves of different kinds, according to the size, operated directly by a float, or through the intervention of levers. Two forms of regulating valve were described. In one, the Curtis valve, the reduced pressure operates upon a diaphragm, which through a secondary valve admits steam to a piston operating the main valve. Another valve is shown in which the reduced pressure acts directly upon a piston connected with the valves and balanced by external weights or springs.

Considerable investigation has been necessary to perfect a meter which would answer all the conditions to be fulfilled in measuring steam. It is evident that if a displacement meter were used, the cylinder development would necessarily equal the piston development, calculated to the points of cut-off of the engines supplied through it. For ordinary slide valve engines, therefore, the meters would have to be practically as large as the engines, or run at very much higher speeds, subject to all the difficulties incident to so doing. A small three-cylinder engine has been developed for use where very small quantities of steam are required, it being expected to pass the steam at full pressure through the meter, and then reduce the pressure afterward, thus measuring only at the greatest density and the smallest volume. The conditions of use in the district now supplied require, however, another form, yet to be described.

Experiments have been made with meters of the velocimeter type, in which the velocity of the current of steam is registered by a series of indices. Mr. Birdsall Holly designed an instrument of this kind, in which the current of steam struck one edge of a series of floats, like those of a paddle wheel. The jet was controlled by a clapper falling by gravity to reduce the opening to a narrow slit, through which steam passed to strike the wheel, when the quantity of steam passing through was limited. The axis of the paddle wheel was made vertical, and upon the lower end of the shaft was a resistance paddle wheel, which worked in water of condensation

collected in the bottom of the case. The steam escaped freely from an opening between the two wheels. This meter has precisely the same kind of variations as any other velocimeter. When passing small quantities of fluid, the slip is very large, and the record is against the supply company. For quantities which may be called moderate to considerable, relative to the size of meter, the rate is remarkably near uniform, when everything is in order. When run to the full capacity of the pipe, the meters are not so accurate. The difficulty with this class of meters lies in keeping the friction constant and preventing wear. There must be some means of carrying the motion of the paddle wheel outside of the case. This is done by driving the axle, which passes through the stuffing box, at reduced speed, by means of gearing inside the case. Notwithstanding this, however, the stuffing box soon gets leaky. The speed of the wheel is quite high, and the bearings wear down rapidly, so that it can safely be stated that the apparatus is not a desirable one for use, except at comparatively low pressures and moderate velocities.

The speaker, at an early date, made up his mind that a successful meter must be based on the principle of flow through an orifice of known size, and with a known loss of head or difference of pressure. Several methods of doing this were tested. In the meter finally adopted, called a "rate meter," the steam flows through rectangular openings, governed by a valve, operated by a weighted piston, balanced on the difference of pressure between the incoming and outgoing steam, the effect of which is that the steam flows through the orifice at a constant difference of pressure. The size of the orifice is regularly registered on a broad paper strip, traversed by clockwork. The result is a diagram showing at any time in the day the quantity of steam used at that time, and the total quantity may be obtained by integrating the chart. When steam is not used, the movable pencil runs on the same line with a stationary one. The paper upon which the meter record is made is printed in divisions of one-half an inch, numbered from one to twenty-four consecutively, to represent the hours of the day, and in starting the paper, the proper division is set at the corresponding time. The time that steam is turned on is shown by the vertical line made by the movable pencil at the beginning of the diagram, and when it is shut off by a similar line at the end; and

evidently the periods when any particular change is made in the quantity of steam used can be determined from the meter diagrams, as well as the quantity used during the intervals. It was at first considered unfortunate that a reliable meter could not be obtained, which, like a water meter, would show by differences of reading the quantity of steam used for the interval between observations directly without calculation, and without the expense of maintaining a time register at each location, and of integrating the charts afterward. This system, however, proved a blessing in disguise. The greatest difficulty in settling with consumers lies in the fact that employés waste the steam. This is particularly the case during the heating season, when steam for various uses is left on continuously during nights and Sundays, thus increasing the time of consumption from, say, sixty hours a week to 168 hours. In many cases, too, the rate of consumption keeps uniform during the night as well as during the day, so that it is an easy matter to more than double the bills. The consumers at first naturally lay the blame to the steam of the steam company, but the meter charts have been the means of enabling the company to satisfy consumers when, and to what extent, the increased bills were due to mismanagement on their premises.

The meters and regulating valves are placed in the pipes leading from the streets to the building, and arranged with shut-off and pass-by valves, so that any part of the apparatus may be put in order without stopping the supply of steam to the building.

[The lecturer then described a watchman's tell-tale system, in which a valve in the pipe leading to the consumer was connected electrically with a watchman's box on the exterior of the building.]

The watchman, being provided with a suitable recording apparatus on his person, visited the several boxes in succession, and by sending an electrical impulse from a portable battery through the watchman's box into the valve, received in turn a record which could be interpreted at the office to show whether or not the valve was open. This apparatus was used while suitable meters were being devised and perfected. [Plans were also shown of the Station "B" boiler house of the company.] At that station it was necessary to erect boilers of 16,000 horse-power on an irregularly shaped plot, seventy-five feet in width, and on an average less than 120 feet deep. To obtain proper floor room, the boilers

were arranged in four tiers, each tier in a separate story twenty feet high, besides which the plans provide for a fifth story for coal storage and a basement for miscellaneous uses. Each floor is arranged for sixteen boilers of 250 horse-power each, which are placed in two rows, to face a central fire room. There are two chimneys, located between the boilers on the sides of the fire room, as near the centre of the building as the shape of the plot permitted.

The whole capacity of the building not being needed at first, the walls were only carried up to an elevation of eighty-eight feet eight inches, and a temporary roof applied, so that at present there are available only three stories for boilers, and one above for coal storage. The south chimney has been practically completed. The north one was originally extended just above the temporary roof, covered and connected with the other by a sheet-iron casing. In the summer of 1885, it was thought desirable to examine the interior of the south chimney and make any necessary repairs to lining, etc., for which reason it was decided to top out the north chimney with a shaft of practically half the area, which would be sufficient for summer use, while the other chimney was being examined.

There are now in place in the building, and fully connected, forty-eight boilers, aggregating 12,000 horse-power.

Customers were first supplied with steam in April, 1882, since which time the steam pressure has been maintained continuously day and night. The coal is brought from the dock in carts and wagons, and dumped from the rear street into small cars in the basement of the rear buildings. These cars are run back to the elevators, lifted to the top of the main building, run out on tracks over coal bins and dumped, the coal descending by gravity through chutes in front of each alternate column, and flowing out as needed on the several fire-room floors, close alongside the fronts of the boilers. The ashes pass from the ash pans down chutes in front of intermediate columns to cars in the basement. These cars are hoisted on the elevator to the roof of the rear building, run out on tracks to the front of that building, and the ashes dumped into a chute, from which they are loaded into carts on the street below.

The boilers are of the sectional type, manufactured by the Babcock & Wilcox Company.

From lack of room, a well-established rule was necessarily disregarded, and the lower portions of the chimneys, instead of being independent, were made part of the building, the section of each being rectangular and corresponding closely to the floor space occupied by one of the boilers. Within the building, the outside of the chimney walls are vertical, the offsets due to reducing the thickness of walls upward being inside the flue. Above the roof the inside of flue is parallel, and the walls are decreased on the outside, each offset being marked by a belt of granite blocks, forming a water table.

The lining extends only to the roof line, and is put in in sections, supported on the internal offsets. The lower part of each chimney above the footings is 32 feet long outside and 13 feet wide. The flue at the top is 27 feet 10 inches long and 8 feet 4 inches wide. The chimneys are topped out at a height of 220 feet above high water, or 221 feet above their foundations. The tops of chimneys are, therefore, 201 feet above the grates of the lower tier of boilers, but only 141 feet above the grates of the upper tier of boilers.

The foundations of the walls of the building are at the elevation of mean high water, and the chimney and column foundations one foot below. An archway is provided through the base of each chimney, as a means of communication between different parts of the basement.

A fixed iron ladder is attached to each chimney, and connected at top with points and at bottom with a cable to form a lightning protector. It was designed to make the top of the south chimney with a projecting platform and iron reticulated balustrade, in which case the chimney would have been 232 feet above high water. It was hoped that by painting the balustrade prominently, it would give the effect of a capital to the shaft without the weight of actual surface projections. For various reasons, however, the top was finished with a granite coping at the elevation of 220 feet above high water, as previously stated, a simple footboard being provided about the chimney, with an iron hand-rail secured in coping stones.

Although the chimney appears slender the narrow way, it is so supported as to have ample weight to resist the overturning moment caused by a wind pressure of fifty pounds per square foot on the area of one flat side.

The shaft erected on the rectangular stump of the north chimney is octagonal in section, with one edge resting on a partition wall built in the centre of the lower flue. The walls are reduced from the outside, with a stone water table at each offset. This chimney is provided with a cap constructed of wrought-iron plates, supported on cast-iron ribs built in the brick-work.

Main steam pipes, sixteen inches in diameter, are arranged in front of each row of boilers on each floor, and connected to two vertical drums, which are in turn connected in the basement to the street mains. By properly adjusting the valves provided, either set of boilers can be connected with or disconnected from either drum. The two drums on each Babcock & Wilcox boiler are yoked together near the rear of the boiler, and from the yoke a wrought-iron pipe is carried nearly to the main pipe in front, but at a lower elevation, where it connects with a copper pipe nearly parallel with the main pipe about eight feet long, which latter connects with a combined stop and check valve on the main. This bent pipe enables the main connection from the boiler to expand freely. The valve at the connection to the main is a simple metal check, which the steam is obliged to raise in order to reach the main pipe, there being provided, however, a screw from the top which can be set down to hold the check in place and make it a stop valve. When the boiler is in use, the screw is run up, and the steam passes out through the check. This arrangement has the advantage that if any rupture occurs in one boiler, the steam and water only from that one boiler will be blown out, the check valve preventing the steam in the main pipe from entering. In one case, by carelessness, water was allowed to get low in one boiler, and one of the headers was cracked. Through the crack water issued on the fire, suddenly generating a current of steam sufficient to blow the door open and force part of the fire out upon the floor. The steam and water practically put the fire out; the other boilers supplied the demand, so that there was no fluctuation in pressure observable on the recording gauge, nobody was hurt, and if there had been no person in the building, the boiler would have taken care of itself without doing injury of any kind whatever. It will be seen that had even this slight accident occurred with all the boilers in free communication, there would probably have been so much steam in the room that the stop

valve could not have been shut until the steam pressure had dropped, and the consumers of the company been greatly annoyed.

The two drums enable steam to be taken to the street by two routes, so that leaks on either can be repaired during the night without interrupting the supply to the streets. This system of duplication was so important that what is called a donkey system was also put in; that is, there is another system of steam pipes extended around behind the boilers with a small connection from each. These pipes have two connections independent of the drums, to the main street pipes in front, and one section is connected to one of the drums.

The principal cause of accidents in the operation of large, long steam pipes, underground or otherwise, arises from collections of water in the mains, when the pipes are cold or there is no steam circulating. The system previously described, of draining the mains to low points, where the water is removed automatically by steam traps, in connection with the plan of maintaining the pressure continuously, absolutely prevents any serious accumulations of water in the mains of the New York Steam Company, when the same are in use. If, however, a main be shut off for making a large connection not originally provided for, for repairs, or any other reason, intelligent care must be taken in restoring the pressure to prevent the pipes from being injured by what are termed "water rams." Any main which has been out of use for a considerable time is liable to have water in it from the leakage of steam past the connecting valves, and its condensation in the disused pipe. Again, when the main is shut off temporarily, water is likely to be introduced from the return mains through the service connections, particularly in winter, when the heating systems are connected. Check valves are put in the discharges of the traps to prevent this, but they are not always in order. To prevent the possibility of any water entering the steam main in this way, orders are given to shut off all the service connections before shutting off a main.

If steam be admitted at the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this in connection with a cloud which forms above the surface will retard rapid condensation, so that in due

time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is therefore perfectly safe to heat up any vessel containing cold water, if the steam can be admitted from the top upon the surface of the water and so maintained. If, however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until its surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water ram. In blowing a small quantity of steam into a large quantity of water, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated, and when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water, which is forced forward by the incoming steam to fill the vacuum.

The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks and sometimes rupture the pipe or break out the end connections. It is not necessary, either, that the end of the pipe be closed. In fact, under certain conditions, a more forcible blow is struck when the end of the pipe is open, as, for instance, when a pipe crowned upward is filled with water, one end being open and the steam introduced at the other, a bubble will in due time be formed at the

top of crown, when the water will be forced in by atmospheric pressure from one end, and by steam pressure from the other, and the meeting of the two columns frequently ruptures the pipe. Evidently, too, the same action can occur without difficulty in a level pipe, but, as previously stated, cannot in a pipe which descends away from the entering steam, so that the latter is *always above* the water.

It is evident from the above that it is always desirable in turning steam on an inclined main to introduce it from the top and let the water out at the bottom of the slope. When this can be done, any workman can be trusted to attend to it. Frequently, however, there are undulations in the pipe, and at times mains which may contain water have to be heated by letting the steam in at the lower end. In buildings, the difficulty can, of course, be prevented by opening drip pipes at the lower end, and letting the water out before the steam is admitted. The same thing can be done with underground pipes, and provision for this should always form part of the plans when it is known that a pipe will have to be heated up in this way. In practice, however, a street system contains so very many absolutely necessary details, that a provision of this kind will not be originally provided for, and at times it will occur that a main which it was expected to heat from the top of a slope may, from something being out of order, necessarily be heated from the other direction. Difficulties also occur in small pipes where the extra labor and expense required to provide special drains for overcoming this difficulty would not be warranted, particularly as another solution of the difficulty is available, even with pipes of considerable size.

If a blow-off opening be provided at one end of a main to be filled with steam, even if such blow-off be at the higher end, and the steam be admitted at the lower end, any water in the main can be driven out of the blow pipe, provided the steam valve be opened sufficiently wide to keep the pressure continuously maintained against the water. The explanation of this is that if the steam supply be limited, the water will run back under portions of the steam, forming bubbles which may suddenly collapse and produce water rams; but if the steam supply be practically unlimited, or at least sufficient, the steam will force the column of water back along the bottom of the pipe, as any vacuum formed will be filled by the

steam driving back the water. There will be a series of small explosions, which will scarcely be heard, and do no harm, and the seething wall of water will be continually forced forward and finally out of the pipe.

Note the distinction in the two methods of operation necessary to suit the conditions. When the steam is on top of the water, it may be turned on as slowly as desired, and it is better to turn it on slowly, as thereby the heavy castings are heated slowly and are not so liable to be strained; but when steam *must* be turned into the lower end of a descending pipe, which *may* be filled with water, the valve must be opened sufficiently to establish a definite current and keep up the pressure. This will not require the valve to be wide open, but the result will be substantially as though it were so open. Practical engineers, who on sea and land have had to do with turning steam on in pipes, naturally recoil from turning steam on quickly in any pipe, and it is very hard to explain to them the difference. The writer has had to take a party of men of this kind, state the reasons for action, and in one case recollects using as an illustration, that if a farmer with a pitchfork could get an officer on the run, the latter could not draw his sword, turn, and defend himself, as he would be run through before he came to close quarters. The principle applies to the water in an ascending pipe. The column of water once started, the steam, if the supply be made sufficient, follows it up so closely, and in such volume, that no condensation can take place sufficiently to stop the onward movement. The clearing of a pipe in this way requires nerve and judgment, but in one case considerable cold water was driven uphill out of a six-inch pipe, 1,400 feet long, with a difference of elevation at the two ends of fully twenty feet, by letting steam in at the lower end and blowing the water out on the surface of the street through a two-inch blow-off pipe. The blow-off pipes are made no larger than this, even for mains fifteen and sixteen inches in diameter, but it is not considered safe to attempt to clear an ascending main of this size with this size of blow-off pipe. All these mains are more nearly level, have blow-offs at low points, near the valves, and can be blown off by putting steam in, at or near the summit. In heating up an eleven-inch pipe, only 400 or 500 feet long from the bottom, the writer has had the flange taken off the extreme end, in order to give the water free exit and prevent the possibility of a ram.

The greatest drawback, in a commercial sense, affecting all systems for supplying a fluid under pressure to underground pipes, is leakage, with its direct loss of fluid, together with the expenses of inspection and repairs necessary in finding and stopping the leaks. Many gas companies in small cities and villages lose one-third the quantity of gas generated by leakage. This proportion is generally reduced as the quantity sold is increased, but even old established companies in large cities lose ten per cent. in this way. Large quantities of water are also wasted in the extended distribution of towns and cities.

The work of the New York Steam Company was particularly well done, with the intention of reducing this loss to a minimum; still, to the surprise of all, the loss from this cause far exceeds that due to condensation. Of necessity, there are thousands of joints and many hundreds of valves with packed valve stems to the mile. If most of the valve stems and an occasional joint leaked but a trifle each, the loss in the aggregate would be comparatively large.

It is to be regretted that time has not permitted a more complete description of apparatus necessary in carrying out the principles involved in the transmission of steam, and of the particular details of the work of the New York Steam Company. Nearly every one of the branches of the subject discussed could of itself be made the subject of a special lecture, full of detail, possessing more or less interest to those who might be called upon to engage in work of this class.

In closing the engineering view of the subject, it may be stated that all the problems are worked out, and that all details are mechanically successful; and, moreover, the returns on the very large investment of the New York Steam Company are sufficient to invite the attention of capital to new ventures of the same kind.

There is a field for another lecture in a popular view of the questions relating to the uses to which steam from the streets can be put, and the advantages of this method of supply. At this time, but a word can be given to this branch of the subject. It will be understood that steam engines of all kinds and sizes in any location from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heating,

either by live or exhaust steam, can be done on any scale, but it is also true that nearly all the *cooking* of a family can be done by steam. Nothing is lacking, in fact, but sufficient temperature to brown bread and put the finishing touch, as it may be called, upon broiled meats. Meats may be cooked perfectly with steam heat, but they cannot, in the open air, be so highly heated as to give the particular aroma which pleases the taste. Meat of all kinds can be roasted in an oven jacketed with steam more perfectly than in one heated directly by fire, as the juices of the meat are kept in, and, becoming heated, aid in cooking the entire mass evenly and thoroughly. Many large restaurants do all their roasting in steam ovens. Boiling of all kinds is very simply performed in jacketed kettles. An attaché of the New York Steam Company has recently made an invention whereby, by planing the top of a steam table and the bottoms of the vessels to be heated, and using simple clamps, stews can be made and water boiled in vessels not jacketed with steam; the heat being transmitted from below, and the rapidity of heating or violence of the ebullition controlled simply by tightening or loosening the clamps. With steam stoves fitted with these various devices, and having in connection therewith small gas stoves for finishing the broiling of meat, and perhaps gas attachments to the ovens to brown the bread and cake, housekeepers will be provided with a great boon. With the exceptions named, which do not form a large portion of the work, every operation can be performed by simply regulating a steam valve. By these means the objectionable features of handling coal and ashes will be entirely removed, and provision for doing most of the cooking, as well as complete facilities for heating water, and in winter for warming the building, be provided "on tap," so to speak, the same as gas and water.

Thus the sun's energy of ages past, stored in luxuriant vegetation and buried with it beneath débris due to cosmic changes, may now be redeemed from the bowels of the earth as coal, transmitted to a distance as steam, and bring sunlight to the household by lightening domestic labor. Power, heat and even actual light may be obtained and manufactures promoted in most inaccessible and contracted places; and one more subject is now available for the exercise of the talents of the engineers of the future, in their efforts to advance still further the comforts and civilization of mankind.

PIG IRON: INCLUDING THE RELATION BETWEEN ITS PHYSICAL PROPERTIES AND ITS CHEMICAL CONSTITUENTS.

BY ALEX. E. OUTERBRIDGE, JR.

[*Abstract of a Lecture delivered before the* FRANKLIN INSTITUTE, *February 6, 1888.*]

After a few introductory remarks, the lecturer said that the subject is an interesting one, not only to the producer of pig iron, but also to the practical founder, the architect and engineer, the machinist and mechanic, and in fact to everyone who has to do with iron or steel in any way; he was glad therefore, to see so large a proportion of young men in the audience, who had come, no doubt, from the various workshops of this great manufacturing city, and hoped that he would be able to impart to them some new facts which might prove valuable in their daily toil.

Continuing, the lecturer said, that although his subject was a "cast iron" one, it was not devoid of literary and even of romantic features, which, time would not permit him to dwell upon at any length. He then spoke substantially as follows:

It is proper, however, to indicate that the subject has a history of great antiquity and interest, and to point out very briefly this path which you may explore more fully at your leisure, and I would commend to your careful study the admirable "History of Iron in All Ages," by Mr. James M. Swank, the Secretary of the American Iron and Steel Association.

The earliest records of iron are to be found in the books of the Old Testament, which make frequent allusions both to iron and steel. In the fourth chapter of Genesis, Tubal Cain is spoken of as "an instructor of every artificer in brass and iron," and the Biblical Chronology places this expert in the seventh generation from Adam. When David was about to build the temple (nearly 1,000 B. C.) "he prepared iron in abundance for the nails for the doors of the gates and for the joinings." An "iron pen" is mentioned in the nineteenth chapter of Job, which was used to engrave upon rocks, and in the next chapter a "bow of steel" is spoken of.

Iron was a familiar metal to the Egyptians, Chaldeans, Babylonians, Assyrians, and other ancient peoples; it is frequently mentioned by classical authors, among whom are Homer, Aristotle and Pliny. Homer speaks of iron discs being given as prizes to the contestants in athletic games, and also of the method of tempering steel by plunging the hissing axe into cold water. Pliny knew of the magnetic qualities of iron, and alludes to the inexhaustible deposits of ore in the island of Elba and in Spain. These mines are still worked, and thousands of tons are annually shipped from them. India has been celebrated for ages for the quality of its steel, and China also claims great antiquity for the process of making iron and steel; the Chinese record minutely describing these methods is still preserved, to which almost fabulous age is accredited by archæologists.

These brief allusions must suffice to indicate the rich store of knowledge upon this branch of our subject, which is available to those who have the time and inclination to pursue it to its fountain head.

It has often been asked, in view of the frequent allusions to the use of iron and steel in ancient times, "why are iron relics of antiquity far more rare than those of gold, silver or bronze?" If you reflect for a moment, the true explanation will be apparent; it is owing to the oxidizable character of the metal, which causes it to rust and crumble away, when exposed to the elements, in a comparatively brief period of time. However, the British Museum is fortunate to have secured, through the labors of Sir Henry Layard, during his explorations at Nineveh, a magnificent and most valuable collection of ancient Assyrian iron armor, shields, battle axes, saws and other objects, which ante-date the Christian era almost 1,000 years. Other specimens were so completely oxidized that although retaining their shape when discovered in the ground, they crumbled to powder on being touched.

Iron is a very widely distributed metal, and is found combined with almost all known elements. Minerals are called iron ores when they contain a sufficient proportion of the metal to pay for its extraction; the ore receives its name either from the locality in which it is found, from its chemical composition, or from its general appearance. Thus we have "bog ore," "magnetic ore," "iron mountain ore," "red and black hematite," "spar ore," etc.

The ancient methods of reducing the metal were exceedingly simple and correspondingly crude. A cylindrical cavity was excavated in the side of a hill and the ore and fuel (charcoal) packed into it, a hole being left at the top and bottom for the draught. When the fuel was all consumed, the metallic iron was recovered amid the ashes. The *regulus* was an impure mass, sometimes resembling wrought iron, sometimes cast iron, sometimes steel, and often a mixture of all three, according as the crude process accidentally altered the proportion of carbon, silicon, etc., in the mass.

The next improvement was in the "Catalan Forge," so named from Catalonia, where it originated. The forge was provided with an artificial draught of air from a rude bellows made of goat skins. Then came the invention of the earliest form of blast furnace, which was a decided improvement, owing mainly to the fact that the process of feeding the ore and fuel and reduction of the iron could be made continuous, thus effecting a considerable saving of labor and also increasing the output of metal. The blast furnace is a very simple affair, consisting of a high stack, lined with refractory clay or fire-brick, oval in shape, having one or more orifices near the bottom, called *tuyeres*, for the admission of air under pressure, and an opening at the top, called the "tunnel head," for the admission of ore, fuel and flux. The fuel formerly used was charcoal, and the quality of the metal (called "pig" iron, from the shape into which it is cast as it runs from the furnace) was fa superior, for certain special uses, to that made by modern processes.

I do not mean to say that I think this is necessarily so, or that it will always be true, but I am compelled to admit that, at this stage of evolution in the iron industry, modern improvements have all been in the line of increased output from a furnace with decreased consumption of fuel, but at the expense of the character of the metal and consequent depreciation of value.

In the old-fashioned charcoal furnace air was blown into it at the ordinary temperature. Furnaces of this character were commonly found fifty years ago throughout Pennsylvania, Ohio and all through the South. We are informed by Mr. Swank that such a furnace, producing four tons of iron a day, or twenty-eight tons a week, was considered to be doing well. We now regard an output of 100 tons a day from one furnace, or even 1,000 tons a

week, as quite an ordinary matter. This extraordinary increase has been accomplished, not by a proportionate enlargement of the furnace, but by lessening the time of reduction of the metal and thus increasing its capacity.

It occurred to some one more than half a century ago, that the waste heat escaping from the furnace might be utilized to warm the air blast before entering the furnace, and thus save a part of the fuel. The air was accordingly passed through iron tubes, arranged in a chamber of fire-brick, and thus heated. A very moderate degree of warmth (say 300° F.) imparted to the air, produced a remarkable effect both in saving the charcoal and in hastening the operation of melting. The iron produced by this method is called "warm-blast charcoal iron," to distinguish it from "cold-blast charcoal iron." Furnaces of this class are extensively used to-day along the Ohio River, in the Hanging Rock region and elsewhere. Improved hot-blast stoves were soon devised, whereby a much higher temperature could be imparted to the air, accompanied by increased efficiency and economy of time, fuel and money.

About 1840, a revolution in the manufacture of pig iron in this country was created by the successful introduction of anthracite coal as fuel in place of charcoal in the blast furnace, although some experiments with anthracite had been made at an earlier date. I recently found upon the shelves of the FRANKLIN INSTITUTE library a printed report, published in 1842, of a commission sent from England to investigate this matter, which stated that iron could never be made with anthracite fuel, and deriding the whole scheme. It was quite a surprise to find such an amusing volume among these dusty archives.

Of late years, coke made from bituminous coal has been extensively used as fuel in the manufacture of mill iron, and the product is called "coke iron," to distinguish it from "anthracite iron."

What is the character of the metal produced by these different processes?

Pig iron varies so greatly in general appearance, color, hardness, ductility, tensile and transverse strength and specific gravity, that one not having expert knowledge upon the subject, might reasonably doubt that the specimens which I propose to exhibit to

you, by means of the megascope, even belong to the same class of metal. One specimen is soft and ductile like lead, and shows a rich, dark color and coarse granular fracture; another is hard as steel, brittle as glass, and white as silver, while between these extremes we have a great range of specimens having intermediate qualities.

You now see upon the screen a photograph taken from a series of "test pieces," (see illustrations, *Figs. 1 and 2*) made from different grades of pig iron, in moulds of uniform size, cast in "green sand," against an iron "chill plate" for the purpose of suddenly cooling one side of the casting. The pieces are arranged in a series with the chilled side uppermost, beginning with a sample which shows no tendency to produce white or chilled metal, and passing, by gradual steps, to metal which crystallizes as white iron through the whole mass. All of these specimens were cast from iron which was perfectly gray in the pig, sufficiently soft to bore readily, varying but slightly in specific gravity, and ranging in transverse strength from 5,000 to 7,000 pounds per square inch. The effect of sudden cooling has developed the white crystalline structure in some of the specimens, rendering them so hard that they cannot be touched with a file, and so brittle that they may be readily broken, and increasing their density to such a degree, that a cubic foot of the white metal weighs nearly sixty pounds more than an equal bulk of the gray iron.

Very little information has been printed in regard to the wide differences in the character of *white iron*, although it is a subject of great practical importance to the manufacturer of chilled castings, and it will, no doubt, surprise many to learn that I have found, as the result of a series of careful experiments (not yet published), that there is as wide a difference in the strength of different specimens of white iron as in those of gray iron. Moreover, there is a vast difference in the ability of white iron to resist disintegration or "spalling" under the repeated impact of hammer blows, dependent upon the molecular structure of the crystals. There is also a decided difference in the density, or specific gravity, and hardness of different specimens of chilled or white iron.

I will now show you a photograph (see illustration, *Fig. 3*) taken from a series of chilled iron test pieces, which were cast in iron ingot moulds made for these original experiments, in which you may observe several interesting features. The samples were all

cast from gray iron, some of which showed no tendency to produce white iron when cast in the ordinary "chill moulds," yet in these small ingot moulds they are chilled throughout the mass. You will observe quite a difference in the molecular arrangement and size of the crystals, and what is still more singular, you will see in all of the square sections a plainly marked cross, or dividing lines, extending from corner to corner of the ingot. White iron always crystallizes in planes at right angles to the chilling surface, and, as the moulds are made of iron, the crystals start from all four sides at the same instant, and meet at points equi-distant from the surface, which may be called the neutral line. By splitting some of the ingots lengthwise, I have found this line extending, plainly marked, through its entire length. It is an interesting phenomenon that the line of demarcation of opposing crystalline forces should be so clearly defined. It will be noticed in the specimens cast in the cylindrical moulds, that the crystals radiate from the centre like the spokes of a cart wheel. Some of the specimens here shown are so brittle that the slightest tap from a light hammer will break them, while others of the same diameter require more than 100 blows to break. Some of them are much harder than others, while the difference in density amounts to nearly ten pounds to the cubic foot, as ascertained by specific gravity determinations. These experiments are novel and interesting from a scientific standpoint, while they also have a practical bearing upon the manufacture of good chilled castings.

Of what is pig iron composed that it should develop such widely varying characteristics? Is the iron itself inherently different in quality, or are these changes due to variations in the proportion of the other elements combined with it? You might suppose that you could obtain answers to these questions from practical melters or superintendents of foundries, but you will find even in the largest foundries lamentable ignorance on such points. As an extremely absurd instance, I may mention that some time ago I visited a large iron foundry, and while conversing with the foreman of the melting department, I asked his opinion of a certain brand of iron with which I was familiar. He replied: "Me and my boss wouldn't have a pig of it on the premises." On being pressed for the reason of his prejudice, he replied: "Well, sir, my opinion is, *it's got too much ammonia in it!*"

The chemistry of iron, in its connection with the manufacture of Bessemer steel, has, from the necessities of the case, been carried to a fine degree of perfection, but it is a matter of surprise that so little is known practically in the foundry and workshop, in regard to the cause of these wide variations, which are a frequent source of difficulty in manipulation of the metal, and loss of time, money and labor. The subject is, however, beginning to attract a share of the scientific attention which has been bestowed upon the chemistry of steel, and upon which the success of that industry so largely depends.

In 1885, Dr. Percy, the eminent English metallurgist, in an address before a distinguished body of scientists, said: "It is not many years since we had to grope about to discover an analysis of pig iron, whereas now we are actually overwhelmed with such analyses. What is now wanted is the man to reduce it to law and order—to evolve from it principles for our sure guidance."

Prof. Turner, of Mason College, Birmingham, Eng., speaking on the same subject more recently, said: "All who are acquainted with the various branches of iron analysis must feel how true the foregoing remarks are in the present state of our knowledge. * * Our knowledge cannot be considered complete until we are able to correctly estimate the mechanical value of any given specimen of which the chemical analysis is known; and conversely, when any given mechanical properties are desired, we should be able to say at once what would be the most suitable composition for the material."

Having quoted the remarks of these distinguished authorities, it may not be inappropriate to read a sentence from a brief paper of my own, ante-dating the above, published in the *Penn Monthly* in February, 1882, bearing upon this subject: "Manufacturers are beginning to realize that pig iron is not a simple substance, but is in reality an alloy, composed of a number of dissimilar elements; that its physical characteristics, such as strength, elasticity, etc., depend upon the percentages of these constituents, and that pure iron, like pure gold, is always the same thing physically and chemically, no matter from what source it may be obtained. We believe that the time is coming when pig iron will be sold on its chemical analysis, instead of on the crude methods of grading at present in vogue, and farther, that, as the naturalist can accu-

rately tell the *genus* of an animal from an examination of a single bone, so the analyst will tell the physical qualities of a mass of iron from an analysis of its component parts."

The great differences observed in physical characteristics of pig iron are due, not to variation of the proportion of iron in the pig (which remains constant within a few points), but to the varying percentages of the other component elements, viz., carbon, silicon, sulphur, manganese and phosphorus, and experience has proved that a change of less than one-half of one per cent. of one of these elements (silicon) is sufficient to make or mar the daily product of at least one important iron industry, viz., the manufacture of chilled cast-iron car wheels.

We will briefly consider the effect upon pig iron of these foreign elements in the order of their relative importance.

The element which exerts the most vital influence upon the character of pig iron is carbon. This is strikingly shown by Mr. Fairbairn, who says:

"The metal in the form of cast iron, containing four per cent. of carbon, has a tensile strength of 18,000 pounds to the square inch, and is worth £3 per ton. Deprive it of this four per cent. of carbon and it becomes malleable iron, with a tensile strength of 56,000 pounds, and is raised in value to £8 per ton. But leave in it one per cent. of the carbon it originally contained, and it will have a tensile strength of at least 130,000 pounds, and its selling price rises to £50 per ton." This price, of course, refers to crucible steel at the time he wrote.

Carbon exists in pig iron in two distinct forms, and upon the relative proportion of each depends, in great measure, the character of the metal. It is present either in the form of graphite or free carbon, disseminated throughout the mass in black shining particles, in which case the iron is exceedingly soft and ductile, or it is in part or wholly combined chemically with the iron, causing the metal, when cooled suddenly, to crystallize in parallel planes, presenting a perfectly white fracture, and the metal becomes harder than steel and extremely brittle; advantage is taken of this peculiar quality in the production of chilled castings, as in cast-iron car wheels, ploughshares, etc.

Cold blast charcoal iron contains a larger proportion of combined carbon than warm blast charcoal, anthracite, or coke iron, hence its peculiar value for chilled work.

Pig iron contains from two and one-half to four per cent. of carbon.

Silicon stands next in importance to carbon, in respect to its effect upon the character of the metal. It exerts a controlling influence upon the chilling properties of the iron, since its tendency is to prevent the chemical combination of the carbon and iron. A very small variation in the percentage of silicon produces a prodigious effect in this particular. In a paper read before the Chemical Section of this INSTITUTE, in 1883, upon the "Genesis of a Car Wheel," I explained at some length the important bearing which silicon has upon that industry; a brief extract will suffice to indicate its scope: "The most important difference between a car wheel and any ordinary casting is the fact that the 'tread' of the wheel, viz., that part which runs upon the rail, is quite different in character from the 'plate' or main body, though cast from the same metal in one pouring. The tread, or rim, is actually harder than steel, thus enabling it to resist not only the wear upon the steel rail, but the still more destructive grip of the brakes, and its average 'life' is not far from 100,000 miles of service. The process by which the hardening of the tread is produced is called 'chilling' (see illustration, *Fig. 4*), * * * but it must not be supposed that all irons possess this property, for it is a comparatively rare one, and little is known, even among expert iron masters, of the causes which produce it. Very recently some light has been thrown upon the subject by the aid of chemical analysis, and scientific investigation will doubtless reveal still more clearly what is as yet but dimly seen. * * * It has been found, for example, that the substance, silicon, which is always present in pig iron, exerts an extraordinary influence upon its chilling power, and a variation of less than one per cent. of silicon is sufficient to make or mar a car wheel; indeed, it has happened that an entire day's work of several hundred men has been spoiled by an excess of one-half of one per cent. of this substance creeping undetected into the mixture."

The notion has long prevailed (like many other fallacies born of ignorance) that silicon produces "blow-holes" or unsound castings, but such is not the case; on the contrary, its tendency is to produce an exceedingly fluid iron, retaining its heat for a long time, owing, I believe, to the fact, not generally known, that the

"specific heat" of iron, rich in silicon, is much higher than a similar grade of metal containing but little of that element. Unfortunately we cannot measure the temperature of molten iron accurately, but I am convinced that pig iron varies in its melting point just as it varies in chemical composition, and that this variation extends through a range of many hundred degrees. It is a modern practice, especially in England, to substitute a small quantity of "silicon pig" in the cupola for the more expensive Scotch irons, in order to obtain soft castings from a mixture of pig iron and scrap. The proportion of silicon in pig iron may vary from three-tenths of one per cent. to three and one-half per cent.

Phosphorus as an element in pig iron tends to render the molten metal very limpid, so that it will take an extremely fine and sharp casting from the most delicate patterns. The famous Berlin castings of reproductions in iron of ancient armor and other ornamental objects, are obtained by using iron rich in phosphorus, but it possesses the disadvantage of rendering the metal brittle and unfit for many practical uses. Through the kindness of Messrs. Thackara & Sons, of this city, I am able to exhibit to you some exquisite examples of Berlin ware, and also a Russian casting representing mounted Cossacks, which is as fine in detail as any bronze casting.

I do not consider it essential to use iron high in phosphorus in order to obtain these artistic effects, and in proof of the assertion I am able now to show you a most creditable experiment made by Messrs. Bureau Brothers, the bronze founders, of this city, for illustration in this lecture, from ordinary foundry iron. The specimen is shown just as it came out of the sand, and it compares favorably in delicacy of detail and fineness of texture with the finished foreign productions, while the design is a meritorious work of art.

The percentage of phosphorus in pig iron may vary from a trace to one and one-half per cent.

Manganese is commonly supposed to exert a hardening tendency upon pig iron, but experience has taught me to regard this as another mistaken notion, it undoubtedly produces a marked effect upon the character of the white crystalline structure. You may readily recognize "a manganese chill" by its coarse lamellar or foliated filaments and by the tendency which it produces to form

white iron or "hard spots" in isolated places throughout the gray portion of a casting. Manganiferous pig iron has been used to produce chilled castings, but it does not make a durable wearing surface; the chilled tread of a car wheel, for example, produced by this method, presents to the eye, when broken through the section, a handsome appearance, but the white metal is comparatively soft; it may be easily bored, and, what is more serious, it crumbles readily under the impact of rapid shocks on the rail.

A remarkable effect is produced upon the character of hard iron by adding to the molten metal, a moment before pouring it into a mould, a very small quantity of powdered ferro-manganese, say one pound of ferro-manganese in 600 pounds of iron, and thoroughly diffusing it through the molten mass by stirring with an iron rod. The result of several hundred carefully conducted experiments which I have made, enables me to say that the transverse strength of the metal is increased from thirty to forty per cent., the shrinkage is decreased from twenty to thirty per cent. and the depth of the chill is decreased about twenty-five per cent., while nearly one-half of the combined carbon is changed into free carbon; the percentage of manganese in the iron is not sensibly increased by this dose, the small proportion of manganese which was added being found in the form of oxide in the scoria. The philosophical explanation of this extraordinary effect is, in my opinion, to be found in the fact that the ferro-manganese acts simply as a deoxidizing agent, the manganese seizing any oxygen which has combined with the iron, forming manganic-oxide, which being lighter than the molten metal, rises to the surface and floats off with the scoria. When a casting which has been artificially softened by this novel treatment is re-melted, the effect of the ferro-manganese disappears and hard iron results as a consequence.*

* A few years ago, Mr. William Wilmington, of Toledo, O., patented a process for softening the hubs and plates of car wheels without affecting the chilled tread by sprinkling powdered ferro-manganese into the head box after the mould is partly filled. It is claimed that new wheels are being made in this manner out of old wheels without the use of pig iron. Mr. Wilmington's patents do not cover the process of softening hard iron in the manner described above.

The percentage of manganese in pig iron may vary from a mere trace to two per cent., or even more.

Sulphur is, without doubt, the most deleterious substance found in pig iron. The other elements all produce effects which may be beneficial for certain purposes, but sulphur is an enemy greatly to be dreaded, since it has a strong affinity for iron, combining with it at a low temperature; it is even possible to bore a hole in red-hot iron by means of a stick of sulphur, yet I have actually seen shrinkage holes and cavities in imperfect castings filled with a composition of melted sulphur, the manufacturer failing to appreciate the deleterious effect which this material will produce upon the iron when the worn-out casting comes back to be re-melted, and this is but one of many blunders which are committed through ignorance on the part of practical founders.

The presence of sulphur in pig iron is due mainly to bad fuel or to imperfect roasting of the ores containing that element, or to improper fluxing. The proportion of sulphur in pig iron may vary from a mere trace to more than one-half of one per cent.

These various elements all produce sufficiently marked effects upon the fracture and general appearance of pig iron to enable an expert, who carefully studies the matter in connection with the analysis of the iron, to estimate by the eye the approximate composition of any given sample within a surprisingly close margin of error. In the case of silicon, I have found by frequent tests that it is possible to predict the percentage of that element within three-tenths ($\frac{3}{10}$) of one per cent. of the actual amount subsequently reported by chemical analysis, and although I have not yet succeeded in estimating with equal success the proportion of the other component elements of pig iron, I believe the method by inspection is susceptible of great development.

Traces of other elements are also found in pig iron, but these do not appear to exert a very important influence upon the character of the metal, and cannot be considered in detail at this time.

It is difficult to define the line of demarcation between pig iron, steel, and malleable iron, since one blends almost insensibly into the other. The following table represents fairly well the extreme variations in composition of these three forms of iron

	Pig Iron.	*Steel.*	*Malleable Iron.*
Iron, ...	90 to 95	98·5 to 99·5	99 to 99·5 per cent.
Carbon, . . .	2·5 to 4	1·5 to 0·5	0·1 to 0·5 "
Silicon, . . .	0·2 to 3·5	Tr. to —	0 to Tr. "
Sulphur, . . .	Tr. to 0·5	Tr. to —	0 to Tr. "
Phosphorus, . .	Tr. to 1·5	Tr. to —	0 to Tr. "
Manganese, . .	Tr. to 2·	Tr. to 2	0 to Tr. "

The development of the iron industry in the United States has been truly marvellous. In 1810, we produced less than 54,000 tons of pig iron; in 1840, less than 300,000 tons; 1860, less than 900,000 tons; in 1885, over 4,000,000 tons; in 1887, 6,417,148 tons, made in twenty-three states and territories, of which Pennsylvania alone produced 3,684,618 tons, or a little over one-half of the total amount. It would thus appear that the agitation over the fear that our state is losing its supremacy as a producer of pig iron is refuted by the facts so carefully gathered by Mr. Swank. In addition to this vast production, we imported last year nearly 500,000 tons of foreign pig iron, besides 283,836 tons of "tin plates," or thin rolled iron coated with tin.

Notwithstanding the progress we have made in every other branch of iron industry, we make almost no tinned iron. Why? Ah! thereby hangs a tale, with a moral appended, which may be respectfully referred to the present administration.

It appears that in the tariff act of 1864 Congress passed a law providing that the duty on "tin plates, and iron galvanized or coated with any metal by electric batteries or otherwise," should be two and one-half cents per pound. Now "tin plates," as you all know, does not mean sheet tin, but *sheet iron coated with tin*, and is the material of which all tinware is made. The plain object of this duty was to encourage the establishment of rolling mills for the production of the sheet tinned iron in this country, and, as we had no native tin, it was desirable to place a comparatively low duty upon that metal. Another clause in the same act provided that the duty on "tin in sheets or plates, terne or taggers' tin," should be fifteen per cent. *ad valorem*. Soon after the passage of this law, the Collector of the port at New York applied (as is stated in the Chicago *Inter-Ocean*) to the then Secretary of the Treasury, for a ruling upon the duty on "tin plates." The Secretary replied, under date of July 22, 1864: "It would appear that an error of punctuation has been made by some one, most

probably by the clerk who engrossed that part of the act. If the comma after the word 'plates' be omitted and a comma inserted after the word 'iron' the true sense will be apparent, which unquestionably is that tin plates must be galvanized or coated with some other metal to bring them within this provision." The Secretary then applied the second clause relating to tin in sheets or plates to the case, so that the duty, instead of being two and one-half cents per pound, was assessed at fifteen per cent. *ad valorem.* The immediate result of this ruling was to give an immense impetus to the business in England, more than fifty rolling mills were established for making tin plates for the American market, and ever since that date we have been consuming more than two-thirds of the entire English production of tin plates, for which luxury we have paid more than $250,000,000 to our English cousins.

Let us turn now to a more pleasing chapter in the history of the development of the iron industry, viz., the manufacture of Bessemer steel, which has grown in the past twenty years from an insignificant beginning to one of gigantic proportions. In 1867, the first steel rails were made in this country at a cost to the consumer of $170 a ton. In 1881, we made 1,355,519 tons, at a cost of $61 a ton. In 1886, we made 2,000,000 tons, at a cost of about $30 a ton, and in 1887 our output was still larger.

Having briefly reviewed the early history of iron and the methods of extraction, the character of the metal as determined by its composition, and the enormous development of the industry in recent years, it is fitting that we should consider in conclusion the various uses to which this product is applied.

We are told that the equipment of railways consumes more than one-half of the world's production of iron, and when we consider that we have more miles of railway in the United States than any other country, or, indeed, the whole of Europe, we can begin to appreciate the magnitude of the needs for the raw material; it is estimated that there are more than *ten million car wheels* required to furnish the rolling stock in this country, these alone consuming more than 2,000,000 tons of iron.

In the manufacture of stoves, ranges, cooking utensils, iron pipe, rolled iron, nails and spikes, fire-arms and cutlery, sewing machines, fire-proof safes, steam fire engines, pumps, hammers,

elevators, planers, saws, axes, general hardware, machinery and all kinds of machine tools, we consume vast quantities of iron, and in most of these products we lead the world both for excellence of workmanship and economy of production.

In the field of artistic cast-iron work we have scarcely made an opening. It is in this direction that I think the greatest opportunity for developing the skill and ingenuity of our young mechanics may be found, and for this reason I have taken the pains to secure specimens of the finest foreign work, and also of our home productions, for your inspection.

Our thanks are due to the various manufacturers who have contributed these interesting and beautiful specimens, and on my own part I desire to thank you for the close attention you have accorded to the subject, as well as for the cordial appreciation of my effort which you have shown.

EXPLANATION OF PLATE.

Figs. 1 and 2 show eight "chill test" samples, cast from different specimens of gray iron arranged in a graduated series, ranging from one showing no tendency to crystallize as white iron, to one which chills white throughout the sample.

Fig. 3 shows the remarkable crystalline structure of white iron ingots cast from gray metal in iron moulds, the crystals forming at right angles to the chilling surface, reveal a well-defined line of demarcation at points equidistant from the surface.

Fig. 4 shows a broken section of a chilled cast-iron car wheel, cast in a "green sand" mould, provided with an iron ring, or "chill" producing a chilled or hard iron tread, with a soft gray iron hub, plate and arms.

PAILLARD'S NON-MAGNETIC COMPENSATING BALANCE AND HAIR-SPRING FOR WATCHES.

By Prof. Edwin J. Houston.

Considerable ingenuity has been expended from very early times in the effort to produce a time-piece whose rate is sufficiently accurate for the determination of longitude. It was not, however, until about the middle of the eighteenth century that even approximate success was reached in this direction.

Trifling changes in the rate of movement of the balance-wheel of a watch make a considerable difference during a run of twenty-four hours. Taking five beats per second as the rate of movement existing in most watches, a variation of but the one-thousandth part of a vibration would make a variation of ninety seconds in each day.

The principal causes that tend to produce a variation in the rate of a well-constructed watch are as follows:

(1) Variations of temperature.

(2) Oxidation of the balance-wheel or the hair-spring.

(3) The influence of position on the balance-wheel.

(4) Variations in the force of recoil of the hair-spring.

(5) Variations in the barometric pressure.

(6) Magnetic retardations or accelerations due to the influence of magnetism on the balance-wheel and the hair-spring.

The influence of changes of temperature on the rate of movement of the balance-wheel arises not only from variations in the distance between the point of support and the centre of oscillation of the balance-wheel, but also from variations in the elasticity of the hair-spring consequent on variations in temperature. A compensating balance-wheel, such for example as that first introduced by Harrison, although correctly proportioned to maintain constant the distance between the centre of oscillation and the point of support despite changes of temperature, would nevertheless be unable to rigorously maintain the same rate unless some device is employed to correct the variations in the elasticity of the hair-spring that accompany changes in temperature. Indeed the variation in the rate of the balance-wheel, due to these latter changes, is greater

proportionally than the variation due to changes in the virtual length of the pendulum of which we may regard the radius of the balance-wheel to consist. Berthoud has shown that eighty per cent. of the variations due to differences of temperature arises from the accompanying differences of elasticity in the hair-spring, while the remaining twenty per cent. only is due to expansion or contraction.

Considerable skill has been reached by practical watchmakers in adjusting the various parts of a watch, so as to avoid variations in the rate of the watch from the first four causes already enumerated. No matter how carefully and with what nicety such adjustments are made they are valueless unless the watch can be protected from the influence of magnetism.

In a practical age like the present, it is scarcely necessary to insist on the very great necessity for accurate, reliable time-pieces. Not only to the navigator, but alike to the railroad engineer, conductor, traveller, artisan or professional man, accuracy in time is one of the essentials to success.

The very remarkable growth of electrical appliances that has occurred during the last decade, renders it easy to injure the best watches by inadvertently bringing them into a magnetic field. A necessity therefore exists for protecting watches from the influence of magnetism.

Heretofore such protection was given to watches by placing them within magnetic shields, which, for the greater part, consisted practically of boxes of iron or some other para-magnetic material. Though affording magnetic protection to watches from comparatively weak fields, such devices are for the greater part cumbersome and clumsy, and, unless quite massive, are unable to protect the watch from the effects of powerful fields.

Mr. C. A. Paillard, the well-known adjuster of watches, at Geneva, Switzerland, has devoted considerable time to the production of a watch that shall be free from the various causes for variation in rate, including those of magnetism. After some fourteen years of experimentation he has succeeded in producing a watch that appears to be absolutely free not only from changes in temperature, but also from the disturbances of magnetism. Indeed Mr. Paillard's watches, from the character of their

construction, appear to be more correctly compensated for variations in the actual length of the radius of the balance-wheel, and for variations in the elasticity of the hair-spring, due to changes in temperature, than the watches that have no magnetic protecting devices; or, in other words, the details of construction introduced into the watch by Mr. Paillard to free it from the influence of magnetism, at the same time make it less liable to be affected by changes of temperature than the watches heretofore produced.

Believing that the effects of magnetism on the rate of a watch were practically limited to the balance-wheel and the hair-spring, Mr. Paillard, by constructing these parts of non-magnetizable materials, has produced a watch that appears to be practically uninfluenced by even the most powerful magnetic fields.

A material suitable for replacing the steel in the compound balance-wheel, or in the hair-spring of a watch, must, it is evident, possess the following properties:

(1) It must be unoxidizable in moist air.

(2) It must be permanently elastic.

(3) It must possess approximately the same elasticity at comparatively wide ranges of temperatures.

(4) It must be non-magnetizable.

After extended and laborious research Mr. Paillard has produced various alloys of palladium possessing the above properties.

These alloys are used for the hair-spring, and for the compensating balance-wheel. The screws placed in the rim of the compensating balance-wheel for weights are made of gold and of platinum. Besides these parts there is a non-magnetic escapement, that is the escape-wheel. pallets, lever, fork and double roller-tables which are made of some non-magnetic substance, generally of a non-magnetic manganese bronze, while in the finer watches an alloy of palladium capable of being hardened is sometimes used.

The train (or wheels) is made of brass, and the pinions, screws, stem-winding mechanism and main-spring, as well as the springs of the hunting-case are made of steel.

Mr. Paillard has patented his inventions in this country as well as abroad. His United States letters-patent are four in number, and are as follows, viz., Nos. 367,158, 367,159, 367,160, and 367,161. These are all dated July 26, 1887, and are entitled patents for alloys.

The subject-matter of the invention described and claimed in No. 367,158, is thus stated in the specification; viz.:

"In spiral or hair-springs for watches and other time-pieces it is very desirable to substitute for steel, of which they are usually composed, a substance that is neither oxidizable nor magnetic, but which shall possess some of the properties of steel; that is to say, small capabilities of dilatation, hardness, and elasticity."

The meaning here is evidently, that the alloy shall possess hardness and elasticity, and small capability of dilatation.

"My invention relates to a metallic alloy and is composed of the metals hereinafter mentioned, or their equivalents, and is useful in the mechanic arts, and especially in the manufacture of balances, hair-springs, and the other parts of watch, clock, or chronometer mechanisms."

"One object of my invention is to produce an alloy which shall be unoxidizable and non-magnetic."

"A further object of my invention is to produce an alloy which shall possess some of the characteristics and properties of iron and steel—viz., hardness, elasticity, and ductility—and, at the same time be substantially, if not absolutely, non-dilatable."

The inventor points out very clearly the necessity that exists for the balances and springs, particularly the hair-springs of watches, to be constructed of materials that are unaffected by rust or oxidation, by ordinary temperatures, or by magnetic or electrical influences. He ascribes previous failures to produce such springs not only to faulty construction, but especially to the fact that no alloys possessing the necessary properties had been discovered. He then points out the great increase in electrical contrivances, and the consequent greater liability of time-pieces to disturbances in the regularity and uniformity of the action of the springs and balance-wheels.

"All of the difficulties mentioned, as well as those experienced by changes of climate, season, locality, whether on land or sea, or either, of altitudes, the descent into mines of whatever character or depth, or from any cause or influence other than mechanical displacement or destruction, are practically, if not entirely overcome by springs or balances properly made of the alloy invented and manufactured by me."

The alloy described in this specification contains the following metals, viz.:

Palladium,	60 to 75 parts.
Copper,	15 " 25 "
Iron,	1 " 5 "

We will for convenience call this alloy No. 1.

The specification states that the preceding proportions or percentage may be somewhat varied, without appreciably affecting the essential characteristics or properties of the alloy.

The process for the production of this alloy is as follows: About half of the palladium to be used is placed with the other metallic ingredients and with a small quantity of borax and powdered charcoal in a clay crucible and heated until melted. The remaining part of the palladium is then added, and when the whole is melted the molten mass is poured into a suitable mould and when cooled is ready for use.

U. S. Pat. No. 367,159, describes an alloy cheaper in its production and suitable for a lower grade of watches, or for certain parts of watches.

The inventor makes the following statement in the specification: "I have found by experiment that the alloy hereinafter described and claimed can be successfully employed in the manufacture of watches and time-pieces for all the parts not required to be non-magnetic and hardly dilatable, as it is not perceptibly affected by ordinary magnetic or other disturbing causes or influences. The cost of its production is also such that it can be profitably and economically used for all the ordinary parts of watches and for the mechanism of the cheaper grade of watches, where perfect uniformity and regularity of movement under all circumstances is not required."

The composition of the above alloy (No. 2) is as follows:

Palladium,	50 to 75 parts.
Copper,	20 " 30 "
Iron,	5 " 20 "

The method adopted for its manufacture is the same as that described for the first alloy.

U. S. Patent, No. 367,160, describes an alloy possessing in the highest degree the properties desired in parts of high-grade watches liable to change of rate.

The inventor makes the following statement in the specification of the above patent: "The alloy which forms the subject of this application I have found by experiment to be non-magnetic, unoxidizable, hardly dilatable, ductile and elastic in the highest degree; in fact, to be capable of withstanding the severest tests without change or impairment.

"In the manufacture of watches, chronometers and other timepieces, where perfect time and the greatest uniformity and regularity of action are required, the balance and springs must be made of such material that they will not and cannot be affected by natural and artificial causes and forces which do not amount to displacement or destruction of the parts."

The following is the composition of the alloy (No. 3) that is described and claimed in this patent:

Palladium,	65	to	75	parts.
Copper,	15	"	25	"
Nickel,	1	"	5	"
Gold,	1	"	2½	"
Platinum,	½	"	2	"
Silver,	3	"	10	"
Steel,	1	"	5	"

The same method is used in the manufacture of this alloy as in the preceding alloys.

U. S. Patent, No. 367,161, describes an alloy which besides possessing the properties of the preceding, possesses the additional property of being raised by tempering to a very high degree of hardness. He uses the alloy as follows: "In order that the best result may be obtained in watches and chronometers, I have found that it is necessary that other parts of the mechanism employed therein, viz., the escape-wheel, escape-lever, guard-pin, and regulator-index shall possess the same characteristics and properties, and in addition thereto be capable of being tempered to a high degree of hardness to prevent wear and abrasion."

The parts above mentioned are the parts which, as we have seen, are sometimes made of manganese alloy.

This alloy (No. 4) has the following composition, viz.:

Palladium,	45	to	50	parts.
Silver,	20	"	25	"
Copper,	15	"	25	"
Gold,	2	"	5	"
Platinum,	2	"	5	"
Nickel,	2	"	5	"
Steel,	2	"	5	"

The process of manufacture of this alloy is the same as that used in the other alloys.

Fig. 1 shows a compensating balance-wheel. It consists as shown of two arms or segments. These segments consist each of

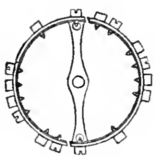


FIG. 1.

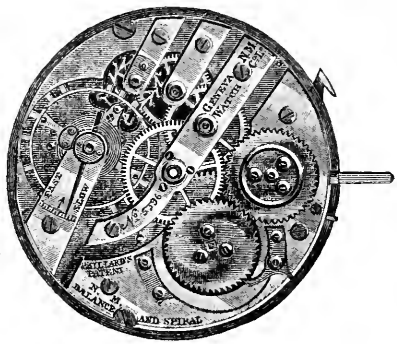


FIG. 2.

two laminæ of different palladium alloys, the coëfficients of expansion of which are so proportioned as to permit them to act as in the compound balance-wheels of brass and steel, to obviate the effects of changes of temperature by preserving constant the dis-

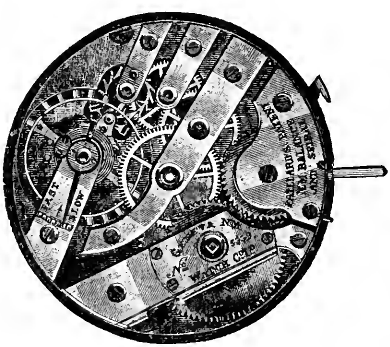


FIG. 3.

FIG. 4.

tance between the point of support of the balance-wheel and its centre of oscillation.

Figs. 2, 3 and *4*, show different movements. *Figs. 2* and *3* are bridge movements, *Fig. 4* is a ¾ plate movement.

Two watches were employed in the experiment about to be described, which I will designate as No. 1 and No. 2.

No. 1, had the Paillard palladium alloys in the balance-wheel and in the hair-spring, and had in addition a non-magnetic escapement. Experiments were made with this watch, both without and with a hunting-case.

No. 2, had the Paillard palladium alloys in the balance-wheel and hair-spring. The escapement was of steel.

The author is indebted to Mr. A. C. Smith of the Geneva Non-Magnetic Watch Company, of New York, for the loan of the first of these watches, and to Mr. Geo. W. Banks, of the firm of Bailey, Banks & Biddle, of Philadelphia, for the loan of the second.

The following experiments were made to test the non-magnetic character of the palladium alloys and the extent of the protection afforded to the watches before alluded to, when placed in various magnetic fields.

Two palladium hair-springs of different alloys were placed in a uniform field, the direction of the lines of force in which was determined by a very thin layer of iron filings. On placing the springs in various positions in the field no change in the grouping of the lines was observable. They were neither concentrated on the palladium alloys nor repelled from them; that is to say, they were neither appreciably paramagnetic nor diamagnetic.

According to the experiments of Faraday and the later investigations of Plücker, palladium is a paramagnetic substance; that is to say, it concentrates the lines of force upon it after the manner of iron. Its paramagnetic properties are however comparatively feeble.

Bearing in mind the paramagnetic character of many of the components of the preceding alloys, their failure to exhibit any of the properties ordinarily recognized as magnetic is interesting from a scientific standpoint. Thus in alloys Nos. 1 and 2 the copper is the only component that is diamagnetic. In alloy No. 2, the steel and nickel are powerfully paramagnetic, and the palladium and platinum are also paramagnetic. The copper, gold and silver only are diamagnetic. In alloy No. 4, all the components are paramagnetic except the copper, silver and gold.

The masking of the paramagnetic properties of some of the components of an alloy would seem to point to the probability of such alloys being formed by true atomic, or chemical combination.

In order to observe the effect of an intense field on the springs

they were placed in the very powerful field of an electro-magnet the massive pole-pieces of which were but a few inches apart. No deflection of the light springs was observed when suspended in this field. When allowed to fall through the narrow gap between the pole-pieces, they fell quite freely. The intense field failed to produce any appreciable magnetism in them.

Similar experiments were tried with the compensating balance-wheel with the same result.

The above experiments may be regarded as establishing beyond doubt the fact that the alloys tried were not paramagnetic substances, that is cannot be rendered magnetic like iron and steel. They can, however, hardly be regarded as conclusive in respect to their diamagnetic character, since the specimens experimented on did not permit of exhaustive trials in this direction.

In order to determine the effect on the rate of time-pieces, that might be produced by external magnetism, watches Nos. 1 and 2 were subjected to numerous experiments, by taking them into various fields, bringing them near the poles of dynamos while generating current, or actually placing them on the poles. No appreciable effects on the rate of the watches were observed.

In all cases the watches were carefully rated before and alter the experiments. For the rating of the watches the author is indebted to Messrs. Jas. H. Kelly and Edwin Corry, of Bailey, Banks & Biddle of Philadelphia, who attended to the rating of the watches, comparing them with the time as signalled from the U. S. Naval Observatory at Washington, D. C.

To subject the watch to a more severe trial the armature was removed from a dynamo-electric machine, and its field excited by the current from a second dynamo. Watch No. 1 was then placed in various positions and for varying times in the field, directly between the edges of one side of the curved pole-pieces. No appreciable alteration in its rate was observed.

The experiments thus made as to the efficacy of the Paillard palladium alloys in preventing change of rate in watches due to external magnetism by placing the same between the pole-pieces of a dynamo were, as will be seen, of an unusual, and, indeed, unnecessarily severe character. It would be impossible in the ordinary use of a watch to subject it while on the person to fields as intense in any position which the observer can take outside the

machine itself. One would in point of fact, have to remain for some time in between the pole-pieces of a dynamo in order to give the watch an equally severe test, and this is of course an impossibility. These experiments were made with the intention of magnifying any small effects that might exist, so that their character could be determined.

The fact, that under these extraordinary conditions, the watch neither suffered any very appreciable variation in its rate, nor had its adjustment seriously affected, shows the extent of the protection afforded by the Paillard palladium alloys. The non-magnetic character of the balance-wheel and hair-springs and escapement of such watches, render this protection quite intelligible.

I have not been able to discover any change in the rate of the Paillard watch that can be directly or indirectly ascribed to the effects of magnetism, when the watch is placed in any position in which it can be brought while in actual use. If any changes in rate do in point of fact occur, they are so extremely minute that I have been unable to detect them, since they are completely masked by the changes, that, even in the best-made watch, are liable to occur from the many other conditions that affect its rate.

In order to obtain an actual record of the rate of a watch subjected to powerful magnetic fields, under conditions in which the errors of temperature, position, etc., were removed, it was necessary that the watch should remain as nearly as possible under the same conditions from the beginning to the end of the experiments. Through the courtesy of the general manager, Mr. A. J. De Camp, of the Brush Electric Light Station, at Twentieth and Johnson Streets, Philadelphia, watch No. 2 was taken to this station, and carefully adjusted until its rate was ascertained. The watch during this time was kept in the same position (lying horizontally with its face upwards) in a fire-proof safe. After it was regulated to a fairly close point, it was placed face upwards on the upper pole-piece of a Weston dynamo-electric machine that was producing a current of twenty ampères, under an electro-motive force of 560 volts. It remained in this position for five minutes, when it was again placed in the safe and its rate taken as before.

The following figures give the data of these experiments, viz.:

February	2d,	1888,	watch set and placed in safe.
"	3d,	"	not rated.
"	4th,	"	6 seconds fast.
"	5th,	"	not rated.
"	6th,	"	20 seconds fast.
"	7th,	"	30 seconds fast, *set* and *regulated.*
"	8th,	"	5 seconds fast; *regulated*, but not *set.*
"	9th,	"	7 seconds fast.
"	10th,	"	9 seconds fast.
"	11th,	"	11 seconds fast.
"	12th,	"	not rated.
"	13th,	"	11 seconds fast.

It will be observed that from the 9th to the 11th of February the rate of the watch showed a gain of two seconds a day, and that on the 13th the watch was running with fair regularity.

On the 13th the watch was placed on the pole of the dynamo for five minutes, as before described, with the following results:

February 14th, ...	12 seconds fast.
February 15th, ...	13 " "

There was therefore no sensible effect on the rate of the watch, since this change of one second per day was quite within the possible range of changes attributable to other causes.

It should be borne in mind that the watch experimented on had its escapement of steel and not of the Paillard alloys. This escapement was a straight-line escapement, and its lever, fork, roller-tables, pallet, and escape-wheel were of steel. The favorable showing of the above experiments, in a watch in which these parts were magnetizable, confirms me in the belief, that a watch in which the balance-wheel, hair-spring and the escapement are of the palladium alloys, cannot possibly be affected by any ordinary, or even more than ordinary magnetic field.

Watch No. 2 was now submitted to a more severe test by holding it in the same horizontal position, face upwards, between the opposite pole-pieces of a Brush, sixty-light dynamo, furnishing a current of nine and one-half ampères, and feeding forty-one lamps. The watch instantly stopped. On taking it away from the pole-pieces it was readily started again. This experiment was repeated several times.

The stoppage of the watch was due, I think there can be no doubt, to the fork coming in contact with the steel roller-table.

The field of the machine was of such a character, that my own watch, though some ten times farther from the pole-pieces than the watch experimented on, was stopped so frequently that I was compelled to take my time from a clock on a distant wall.

The watch though placed in a field that stopped it was not affected sensibly in its rate when removed therefrom.

There was thus obtained a practical demonstration of what was to be expected from the non-magnetic character of the balance-wheel and the hair-spring. If these are non-magnetizable the watch should not, apart from considerations hereafter considered, be affected by magnetism.

At the same time the experiment seems to suggest the advisability of making the escapement of all watches of non-magnetizable materials, either of manganese bronze or, preferably, of some of the palladium alloys. Where the deformation of the case or train due to magnetic stress, is to be feared, it would appear advisable to replace the steel springs for the hunting-case by, say manganese bronze. Where such is not to be feared, the steel case-springs probably act as a species of magnetic shield, causing many of the lines of force of an extraneous field to pass through them.

I am satisfied that the stoppage was due to the magnetic character of the escapement, since a watch with the balance, hair-spring and escapement all of non-magnetizable material, when placed in the same field under exactly similar conditions was unaffected.

In order to give some idea of the strength of the magnetic field of the Weston dynamo-electric machine used in the preceding experiment, I would state that a watch provided with what is termed an *anti* (sic) magnetic shield, was instantly stopped when placed under similar conditions. This watch is a very fine one that belongs to a well-known electrical engineer. In order to avoid changes in its rate due to magnetism, he had a gold balance-wheel placed in the watch, but had it subsequently removed since the changes in the rate of the watch due to variations in temperature were greater than those due to magnetism. An ordinary balance was then put in together with the magnetic shield before referred to.

The failure of magnetic shields to protect watches when subjected to the fields it would be exposed to in the neighborhood of powerful dynamos is to be expected, since the small mass of material used would be insufficient to carry all the lines of force through the shield and thus protect the watch.

Since the watches experimented on contain magnetizable materials, such for example as the main-spring, regulator, steel screws, and, in hunting-cases the large case-springs, they must of course acquire a field of their own when taken into a sufficiently powerful external field, and the field they thus acquire they must as a matter of course keep indefinitely. The question therefore arises whether this field must not affect the watch's rate; for, since the balance-wheel and hair-spring are metallic and conductors of electricity, they might, in their to-and-fro movements through the watch's magnetic field, so cut the lines of force, as does the wire on the armature of a dynamo-electric machine, as to effect a retardation of the balance-wheel, and consequently change the rate of the watch.

That such an effect is not produced by the watch's own field to any appreciable extent is shown by the fact that the experiments before recited failed to sensibly affect the rate.

In order to ascertain whether any such effect is in point of fact produced under any circumstances the following experiment was made. The previous experiments having convinced me that so far as the field of the watch was concerned, or even its field when reinforced by comparatively powerful external fields, was unable to produce any measurable results, arrangements were made to obtain an exceedingly powerful field directed so as to produce its maximum effect, and to expose the watch to such a field for a comparatively prolonged time.

Watch No. 1 was exposed to the field of an Excelsior machine from which the armature had been removed and the field excited by the current from a Brush sixty-light arc machine.

In order to concentrate this field on the balance-wheel, massive conical pole-pieces of soft iron tapering to a rather sharp point were attached to the inner pole-pieces of the machine, leaving a space between them just sufficient to introduce the watch, the pole-pieces just touching its face and back respectively. The watch was then placed horizontally, face upwards,

so that the point of the conical pole-pieces came above and below the edge of the balance-wheel nearest the edge of the watch. Under these conditions, the balance-wheel, in its to-and-fro motions, moved alternately into and out of the field, cutting the lines of force at right angles to its motion, and should experience retardation, as in the case of the well-known copper-disc experiment, or, indeed, as already stated, as in the case of an ordinary dynamo-electric machine.

The watch was then left in the field so provided, and in the position stated, for one hour. On its removal from the field it *was found to have gained fifteen seconds.*

A previous experiment made under somewhat similar conditions, in which the field was neither quite so strong, nor so well defined, the conical pole-pieces not being employed, an exposure of forty-five minutes caused a gain of 8¾ seconds.

I had previously expected that the retardation of the balance-wheel would be attended by a retardation of the watch ; that is that the watch should lose rather than gain time. Due consideration however will show that the retardation of the balance means a decrease in the arc through which it moves, and this must necessarily be attended by a greater number of oscillations in a given time. In other words the watch, it would appear, must *gain* and not *lose* when moving through the resisting medium of an intense magnetic field.

It is thus shown that a watch in a magnetic field acts like a dynamo-electric machine, and may, under suitable conditions, generate current and experience a change of rate. It might be interesting to inquire whether such temperature changes are produced by such currents as to affect the rate, when the watch is placed under the extraordinary conditions related in the last experiment.

It is a significant fact that, even after the prolonged exposure to the extraordinary field employed in this experiment, no appreciable change in the rate of the watch was observed, although its rate was carefully noted for five days afterwards.

In conclusion, and as a result of all the experiments made, I believe that a watch containing the Paillard non-magnetic compensating balance, hair-springs, and escape-movement can safely be carried into even the most intense magnetic fields without suffering

any appreciable change in its rate; and, that while on the person of its wearer, it cannot possibly be brought into a magnetic field sufficiently strong to alter its rate.

Mr. Paillard has therefore conferred a great boon not only on the electrical engineer but on all those to whom correct reliable time is a necessity.

CENTRAL HIGH SCHOOL,
Philadelphia, February 20, 1888.

BOOK NOTICES.

STEAM BOILER EXPLOSIONS. Thurston, R. H. John Wiley & Sons, New York. 1887. pp. vi–173; 12mo.

This little work, by Prof. Thurston, is a very complete statement of the causes of boiler explosions, and will serve the "excellent purpose of showing that the element of mystery commonly exists only in the imagination of writers * * * and that the causes of accident are wholly preventable and controllable." Being nearly free from formulæ, the information it contains can be readily understood by those having the care of boilers, and should be carefully read by them. The matter advanced has been understood by engineers for some time, but the collection of the facts here given puts the matter in a convenient shape.

The first part of the work is devoted to showing that the energy actually contained in a boiler in use is more than sufficient to produce all the destructive effects usually accompanying explosions. The cause of explosions can always be found to come under one of the following heads: (1) defective design; (2) bad construction; (3) decay; (4) mismanagement. The absurdity of the many theories of the production of gas, electricity, etc., and the necessity of frequent and intelligent supervision are plainly pointed out.

Tables of statistics relating to boiler explosions are given, and also the results of boiler inspections, made by the Hartford Steam Boiler Inspection and Insurance Company. Their inspections show that out of 6,453 boilers in which defects were discovered, 927 were dangerous; and out of 4,409 defective boilers, 457 were dangerously so. A statement of Colburn's theory of the method of explosions and Lawson's experiments to corroborate the theory are dealt with fully.

The bad effects of overheating the iron are shown to be due more probably to the weakening of the iron rather than to the subsequent violent evaporation. The danger of low water and increase of sediment over heating surfaces, is pointed out, as well as the fact that the pressure will rise very rapidly in a boiler in use from which no more steam is taken. Typographical errors make both the formula for determining the time for a given increase of pressure and the application of the corrected formula to the first case incorrect.

Local decay, caused by corrosion, pitting, grooving, etc., shows the necessity of frequent inspection. The advice given under the head of emergencies is excellent, and should be thoroughly understood by those having the actual charge of boilers.

The last part of the book is devoted to instances of explosions, giving their probable cause and destructive effects.

As in Prof. Thurston's other works, throughout this book, where English units are used, their French equivalents are given, but after one becomes accustomed to *not* seeing the quantities in parentheses the annoyance disappears.

H. W. S.

RICHTER'S INORGANIC CHEMISTRY. Third American from the fifth German Edition. 12mo. Cloth, $2. P. Blakiston, Son & Co., Philadelphia.

The book before us is the English translation of a well-known German text-book on chemistry. The appreciation of its merits in this country is shown by the fact that the issue of a new American edition has followed rapidly the issue of each of the last three German editions. We have before us the third American edition, translated from the fifth German one. As stated by the translator, the present edition contains a rather extended section upon the thermal behavior of bodies, and throughout the work frequent occasion is taken to call attention to the dynamical side of chemical reactions. The sections upon the pressure and condensation of gases, and that upon the dissociation phenomena, have also been considerably increased, while new facts relating to the elements and their derivatives, to their preparation, etc., have been introduced in their proper places.

The general points of excellence of Richter's book are well known to those (and the number is now quite large) who use it with their classes. They consist in accurate and clear statements of the most generally approved views of chemical theory, a philosophical method of developing the study of the chemical elements and their more important compounds, taking them in natural groups, and constantly calling attention to the group-characters, both the points of resemblance and the gradual differentiation within the limits of the group. This method of treatment has become necessary, if we are to lay any stress upon the "periodic law" theory of Mendelejeff and Lothar Meyer, which makes the properties of the elements and their compounds periodic functions of their atomic weights. The most recent facts with regard to the different chemical elements and compounds mentioned are, in general, well stated. We do not think sufficient prominence is given to the explanation of the "ammonia-soda" process, which, as this edition states, furnishes half of the carbonate of soda made in Europe, and, with the cryolite process, makes all that is made in this country. No mention is made of the manufacture of malleable nickel by the Fleitmann process, which has assumed considerable importance in Germany, nor is any mention made of the newer processes for obtaining metallic aluminium, which have attracted such general attention recently.

We wish, too, that the author, or at least the translator, would drop the use of the terms "nitric oxide" and "nitrous oxide" as applied to NO and N_2O, respectively, as this irregularity only perpetuates the confusion already too great in naming non-metallic oxides.

The book is clearly printed and presents a most attractive appearance.

S. P. S.

MECHANICS OF MATERIALS. Church, I. P. New York: John Wiley & Sons. 1887. 8vo. pp. xvi, and 195 to 514.

This work, which is a continuation of statics and dynamics by the same author, treats of the general laws governing torsion, flexure, tension and compression and their practical application. While there is but little new in the results deduced, the method of treatment is one that makes it excellent as a text-book. After the derivation of the formula governing any particular case, and which is done in the simplest manner possible, there are examples given, such practical ones as engineers are often called upon to solve, and the application of the principle is learned as soon as the principle itself. The graphical method of solution is used freely throughout that part of the book treating of arches, girders, etc., and a sufficient quantity of the principles of graphical statics and graphical arithmetic is given to enable the students to understand their application. The text is freely illustrated, each illustration having on it in its proper place all the data required for its easy understanding. The stress laid upon correct numerical substitution, and the proper use of the units of measurement, together with the examples given, make it one of the most practical books published on the subject, and its freedom from typographical errors makes it an excellent reference book.

H. W. S.

A TEXT-BOOK OF ROOFS AND BRIDGES. By Mansfield Merriman. Pt. I. Stresses and Simple Trusses. New York: John Wiley & Sons. 1888. 8vo. pp. 118.

All who are acquainted with the works of Prof. Mansfield Merriman, of Lehigh University, will be glad to learn of the publication, by John Wiley & Sons, of a new text-book on roofs and bridges by that author. Perhaps there is not much in the book that is new to those already well versed in the subject, but it is especially adapted to the needs of beginners.

To such, the principles of the science could scarcely be made clearer or stated more concisely, and in this consists the great merit of the author's works.

There are only 118 octavo pages, printed in large type, so that the book may easily be finished in one term of a college course. The volume just published is only Part 1 of a proposed course of four parts, and consists in the treatment of the computation of stresses in roof trusses and in all the common styles of simple bridge trusses; the second part will treat of the analysis of stresses by graphic methods; the third part, of the design of a bridge, including the proportioning of details and preparation of working

drawings; and the fourth part of the discussion of cantilever, suspension, continuous and arched bridges. These, in connection with the author's "Mechanics of Materials," would make an excellent course. Besides the bare mathematical analysis of the stresses, there is much information of a descriptive nature laying stress on the importance of practical knowledge, judgment and skill in the designing of connections, determination of data for the computations, etc., so as to produce a structure of least cost and greatest stability. The author has succeeded in giving a rule, easy of practical application, for finding the maximum stresses due to the wheel loads as actually existing, instead of assuming the loads to be uniformly distributed with a uniform locomotive excess as usually done.

It is to be hoped that the other parts of this course will soon be ready for publication. S. S. E.

General Specifications for Highway Bridges of Iron and Steel. By Prof. J. H. L. Waddell, C.E. Macdonald & Spencer, Kansas City. 8vo. pp. 45.

In this paper the author has started with the most instructive lessons of experience as derived from the failure of highway bridges, reported by Prof. Geo. L. Vose. A short chapter is devoted to the "letting," another to the rule-of-thumb manner of proportioning and assembling, and the next to the means by which these defects may be avoided. The author proposes an association of highway bridge builders to secure better results for all parties to the contract and a greater guarantee as to the safety of the travelling public. The paper closes with a set of very carefully drawn specifications for structures of this class, in which the writer is a recognized authority. It will be found to be a valuable contribution to bridge literature and especially useful to road and county commissioners. H.

Tables for Calculating the Cubic Contents of Excavations and Embankments. By John R. Hudson. New York. Vol. 2. John Wiley & Sons. 8vo. pp. 82.

The already pretty well overloaded literature on the computation of earthwork volumes is still further augmented by the publication, by John Wiley & Sons, of Volume II of tables by John R. Hudson, M. Am. Soc. C.E. The work contains twenty-three pages of text, and sixty pages of tables. There are also some specimen pages showing form of cross-section sheets adapted to his methods of computation.

The author calls attention to article 9, in which is given a short and simple rule, adapted to "three-level-ground," to take the place of the ordinary method of averaging end areas. The process involves the inspection of tables, and besides this, consists only of addition and subtraction. By comparison of both methods of computing an example he shows a saving of one-third the time required in the common way. This article contains another method of arriving at the same result equally short, as well as a formula giving the prismoidal contents with one-half the labor necessary when the ordinary

form of the prismoidal formula is used. By using his tables of side triangles the computation is much abridged, as the calculation of end areas is dispensed with. Article 8 shows the method of making the prismoidal correction, giving results differing but little from the true prismoidal contents. In article 11 methods for cross-sections for five or more heights are given. There are in all forty-six tables, thirty-six of these being tables of contents for level cross-sections and side triangles for different widths of road bed and side slopes.

It would be a great labor to examine and compare all the methods of abridging earthwork computations that have been published, and determine which one gives the most correct results for the least labor. But we think that Mr. Hudson's tables are well worthy of a careful examination by anyone who has much of this kind of work to do. S. S. E.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

Comparison of Water Gas with Illuminating and Generator Gas.—Ferdinand Fischer, in *Zeitschrift für die chemische Industrie* (1887), **47**, treats at considerable length of the conditions under which water gas or generator gas seems likely to replace illuminating gas. He considers that metallurgical works. chemical manufactories, and all large establishments of this kind are likely to make free use of water gas, if the cheaper forms of fuel like coke, scrap, etc., are to be had. Water gas is now used at Witkowitz, and will shortly be used at Hörde also, for the Siemens-Martin ovens, the welding ovens, and at Essen for welding axles. It is also adapted for sugar works for burning the lime, and in burning fire-brick and fusing glass for the final high heating. In chemical establishments water gas will find a widespread application; first, as a substitute for ordinary illuminating gas, because it burns with smokeless flame, and readily yields a higher heat; and second, because of the high temperature and the amount of hydrogen, it is adapted to many decompositions, like that of chloride of magnesium. The general introduction of water gas, in the opinion of Fischer, will surely come as soon as it is specially adapted to the different kinds of coal, in which case it will be found desirable first to deprive the coal of volatile matter, as is now done in gas making, and then to work up the fixed carbon into water gas, which, after the collection of the valuable side products, can be mixed with the previously formed illuminating gas. In such a case, as it will not matter whether all volatile matter has been driven out of the coal or not, in the first stage of the process, much lower heat can be used than is now customary in gas works. It is even possible that our present cumbrous methods of gas making will be replaced by others in which coal will be handled exclusively by machinery, first partially deprived of volatile matter, and then at once run into the generator for water-gas making as the second step.

For the supply of a district with illuminating, heating and power gas, only the illuminating and water gas can be considered. In this case, illuminating gas is distinctly less suited, as it contains only twenty per cent. of the heating value of the coal, requires much manual labor in its production, and can only be produced from certain kinds of coal. The water gas process, on the other hand, yields forty per cent. of the combined value of coke and anthracite, as a gas of high calorific value, and by corresponding improvements in the process will likely yield forty-five percent. This gas can easily be used for illuminating purposes by the aid of a magnesia comb like that of Fahnehjelm (or the von Welsbach net of metallic oxides, and the Sellon-Lewis platino-iridium cage) and for heating purposes is much more convenient, and in most cases much cheaper than coal gas. S. P. S.

"SALUFER" is the name of a new antiseptic, which is being introduced into notice. It is sodium silico-fluoride. The activity of its saturated solution is said to be equal to that of a one-thousandth corrosive sublimate solution. Its freedom from poisonous qualities and its stability will make it a material of great value, if its antiseptic qualities are thoroughly substantiated. A paper, referring to the new antiseptic, by Mr. F. H. Rosengarten, appeared in the December number of the *Amer. Jour. of Pharmacy.* S. P. S.

ON THE DECOMPOSITION OF PETROLEUM NAPHTHA ON HEATING.—It has long been a known fact that in the distillation of Caucasian petroleum, some constituents decompose even at relatively low temperatures. This is shown in the formation of coke deposits in the crude oil stills at Baku, which, therefore, to avoid a burning through, have to be cleaned every seventeen to thirty days. This decomposition of the Caucasian oil did not attract much attention until recently, when Alexejew patented a process for obtaining relatively low boiling products from the crude naphtha by a peculiar process. This consists in distilling in an atmosphere of illuminating gas accompanied by a continuous decomposition of the naphtha. Prof. Lissenko has therefore had Rosenbladt study this process in the laboratory of the Mining School at St. Petersburg, in order to find out the most favorable condition for the decomposition of the naphtha without the use of illuminating gas. The apparatus consisted in a round-bottomed flask of difficultly fusible glass, to the neck of which was fitted a dephlegmator tube, 1·5 cm. wide and 40 cm. in length, from which issued laterally four delivery tubes, set at different heights, 6 cm. apart. In the beginning of the distillation the vapors issued from the top tube, while the three lower ones were closed off. When the vapors cease to issue here, this tube is closed and the next lower one is opened and connected with the condenser and receiver. When this ceases to deliver, the third and eventually the fourth delivery tubes are opened and similarly connected. To determine the temperature at which the distillates were given off, a long glass tube sealed below was lowered through the dephlegmator tube, and in this, glass cylinders containing metallic zinc, bromide of silver, chloride of silver and chloride of lead, were placed. By the fusion of these several substances, the temperatures 400° C., 434° C., 457° C. and 501° C. were determined. The temperature best fitted for the decomposition of the naphtha

was found to be between 434° C. and 457° C. Similar experiments conducted on a larger scale in Nobel's technical laboratory in St. Petersburg, gave 400° C. as the best temperature for this decomposition. Operating in this way with naphtha residues (from which burning-oil fractions had been distilled off) Rosenbladt got sixty-four per cent. of a distillate of sp. gr. 0·805, thirty per cent. of sp. gr. 0·860, and four per cent. of a coke-like residue. The first distillate (sp. gr. 0·805) gave, on fractioning:

Up to 110° C.,	10 per cent. of a fraction of sp. gr.	0·703
From 110° to 135° C.,	10 " " " "	0·756
" 135° to 175° C.,	10 " " " "	0·786
" 175° to 255° C.,	20 " " " "	0·813
" 225° to 235° C.,	10 " " " "	0·828
" 235° to 295° C.,	10 " " " "	0·849
" 295° to 305° C.,	10 " " " "	0·847
Residue,	20 " " " "	0·867

The second distillate (sp. gr. 0·860) separated on cooling solid hydrocarbons, while the first mentioned above (sp. gr. 0·805), even after purifying with sulphuric acid and alkali, showed a yellow color and a pyrogenic odor. On separating into fractions by the second distillation, however, it yielded an unexceptionable burning oil, which showed no tendency to become yellow on exposure to the air.

Theoretically, then, Lissenko has solved the problem of decomposing the heavy portions of the crude naphtha into lighter ones, which can be burned as illuminating oil. Practically, the process will not be carried out at Baku, with the present prices of crude oil, as the process involves several distillations and a lengthening of the time necessary for the production of the illuminating oil, so that it is cheaper to take the smaller yield from the crude oil and throw away the residues than to work them up for burning oil.—(*Russian Mining Journal, 1887—349.*) S. P. S.

Report on Tanning Leather, Etc., in Royal Jubilee Exhibition, Manchester. Watson Smith, *Journal Society of Chemical Industry*, **6**, No. 12.—The art of manufacturing sole leather, and some species of upper leather, has been known from ancient times, but it is only during the last half century that tanning has become a science, and that the value of chemistry has been appreciated by the tanner. The manufacture of strap-butts is a growth of the present century, and it has naturally developed with the increased application of machinery throughout the world, until now it may be estimated that there are manufactured from English strap-butts alone upwards of from 35,000,000 to 40,000,000 feet of belting per annum. The manufacture of "clog-butts" is mainly confined to this country (England), and is not an increasing industry. Probably less than 1,000,000 pairs of clogs are made annually in England, and these are made entirely from English leather. The number of hides and skins imported into England for home consumption may be roughly estimated at about 9,000,000 per annum, the bulk of which come from South America, the Cape, Australia, Brazil, Madagascar and the West Indies. With regard to English hides, if we take as a basis the amount of beef consumed in Lancashire, the supply of hides will be about 195,000 to every 500,000 inhabitants. This would mean a total of about 10,000,000 English hides per

annum, and about 1,000,000 calf-skins. The value of these hides (in all about 20,000,000) is probably £15,000,000 to £18,000,000 sterling, and this value, after the cost of tanning, and perhaps currying, has been added, will probably be increased to something between £30,000,000 and £40,000,000 sterling.

The chief tanning agents used in England are oak bark, stripped in English and Belgian forests, valonia from Smyrna, myrabolams from the East Indies, divi divi, Mimosa bark, hemlock and other extracts used in smaller quantities. The staple agents used in currying are cod oil, from Newfoundland, and tallow, melted in England or imported from Russia.

Specimens of heavy and light sole and insole leathers, also army, hydraulic and other machinery leathers were exhibited. The chief characteristic of these materials is their fineness of texture and compactness of pattern, and these qualities are attained by special preparation.

The ordinary sole leather is tanned for nine months in oak bark liquors and three months in strong valonia liquors to give solidity. The leather for army and hydraulic purposes is continued six months longer in the valonia liquors. The "offal" or insoling is tanned for a period of six months only.

The following materials employed in tanning are also shown: *Tanning Extracts.*—Clarified oak, myrabolam, sumac, valonia, larch and divi divi extracts. *Ground Tanning Materials.*—Extra best Palermo sumac, fine ground myrabolams. *Raw Tanning Materials.*—Sumac, divi divi, myrabolams and valonia. H. T.

ESTIMATION OF TANNIN IN EXTRACT OF SUMAC.—T. C. Palmer (*Jour. of Soc. of Dyers and Colourists*, **3**, No. 11).—American manufacturers attempt to purify the extract by removing pectin, which is the supposed cause of the fermentation, or to prevent fermentation by the addition of a germicide. The following is the summary of the author's examination of the unpurified and purified extracts:

THREE SAMPLES EXTRACT SUMAC.

	Ordinary.	*Once Refined.*	*Twice Refined.*
Per cent. of tannin by hide powder after removal of pectin,	26·26	24·70	17·88
Per cent. of tannin by Löwenthal's after removal of pectin,	30·24	26·51	17·83
Per cent. of tannin by Löwenthal's before removal of pectin,	38·48	27·14	18·96
Excess by Löwenthal's after removal of pectin,	3·98	1·87	0·05
Excess by Löwenthal's before removal of pectin,	12·12	2·44	1·08

This table plainly shows: (1) That a like result is obtained by the two methods in the case of the extract that has been refined during the manufacture. (2) That a partially refined extract (one containing more pectin) gives a certain discrepancy between the methods. (3) That when the pectinous matter is still larger, the discrepancy is greater still. This, it is to be noted, is after the pectin has been removed. If the Löwenthal method is applied before the removal of the pectin, the results are still more discordant. It is, therefore, evident: (1) That the gelatin, salt, and acid of Löwenthal's method precipitate out of this extract other matter besides tannin, giving

thus too high a result. (2) If this other matter, which is evidently the "pectin" of the extract, is removed by alcohol precipitation, the results are still high, except when the percentage of the pectin was at first very small, showing the presence of some body, doubtless derived from the pectin, which has escaped separation because soluble in alcohol, and which is, like pectin, counted as tannin by Löwenthal's method, but which hide powder refuses to take up. It is exceedingly probable that this substance is the so-called *metapectic acid*, formed from the pectin after the manufacture of the extract. If a way can be found for its removal, one of the difficulties of tannin estimation in sumac extracts will be overcome; that is, if it is desirable, as Proctor thinks, to retain Löwenthal's method for sumac. It seems to the writer that the hide powder method, when properly used, is preferable, since, as shown above, one of the errors of Löwenthal's method is that which does not seem to affect the hide powder method. H. T.

SILICON MON-OXIDE. Charles F. Mabery (*Am. Chem. Jour.*, **9**, 14).—When silica is reduced in the absence of metals in the Cowles' electric furnace, the product contains a varying quantity of an amorphous, greenish-yellow, or sometimes deep-green substance, having a vitreous lustre. It is always found between the unreduced oxide and the silicon, which seems to show that it is the result of a partial reduction. Analysis of this substance indicates that it is silicon mon-oxide. It is attacked by hydrofluoric acid, but not as readily as the di-oxide, and is slowly changed to the latter by fusion with a mixture of alkaline carbonate and potassium nitrate. A determination of its specific gravity gave 2,893, a figure somewhat higher than the density of silica.

W. H. G.

ON A PARTIAL SEPARATION OF THE CONSTITUENTS OF A SOLUTION DURING EXPANSION BY RISE OF TEMPERATURE. J. W. Mallet (*Chemical News*, **56**, 146).—In a thermometer containing colored alcohol, on several occasions when rise of temperature occurred somewhat gradually after rather severely cold weather, the upper part of the column of liquid was colorless or nearly so, while no deposition of any solid coloring matter could be seen in the bulb or the lower part of the tube. Colorless alcohol had apparently separated by expansion from still perfect solution left behind.

This led to making some experiments with solutions, partly aqueous, partly alcoholic, of several colloid substances, such as starch, tannin, caramel, albumen and gelatin. Each solution was placed in a flask of about half a litre capacity, which was brought to near 0° C. by being surrounded with ice, filled to the mouth with the solution, and closed by a cork traversed by a glass tube, about 4 mm. interior diameter, 15 or 20 cm. long, and having a glass stop-cock in the middle of its length. The ice having been removed, the temperature of the flask and its contents was allowed to rise gradually until the column of liquid in the tube, originally one or two centimetres below the stop-cock, had reached to about as far above it. The stop-cock was then closed, and the small portion of liquid above it was submitted to appropriate tests for the substance in solution in the contents of the body of the flask. In contrast with a sample of equal volume taken from the flask itself, the por-

tion which had been slowly driven up by expansion was found to contain a diminished amount of material in solution, often a very notably diminished amount, and in two or three instances practically none.

The author proposes the term apantlesis to signify this draining away of some of the molecules of the solvent undergoing expansion from those of the colloid solid in solution. W. H. G.

ACTION OF CARBON TETRA-CHLORIDE ON OXIDES. E. Demarçay (*Comp. Rendus*, **104**, 111), and Lothar Meyer (*Berl. Ber.*, **20**, 681), independently. —The preparation of metallic chlorides by the action of chlorine on a heated mixture of the oxide and charcoal, leaves nothing to be desired, if the chloride is readily volatilized, but if it is not, there is often difficulty in separating it from the mixture of charcoal or oxide if an excess of either has been employed. The reaction of the oxides with carbon tetra-chloride would avoid this inconvenience. The authors' results agree in the main; when the reaction occurs, the gaseous products are carbon di-oxide, carbonyl chloride, chlorine, hexachlorethane, and according to Meyer, carbon mon-oxide. Both agree that aluminium oxide is readily reduced and that silica is not. Meyer states that the oxides of beryllium, magnesium and cerium are reduced, while titanium, boron and zirconium oxides are not. Demarçay reduced, in addition, chromium, tantalium and niobium oxides, and states that zirconium oxide is reduced slowly and titanium oxide rapidly at 440°. Meyer does not give the temperature. W. H. G.

VOLATILIZATION OF DISSOLVED SOLIDS DURING EVAPORATION OF THE SOLVENT. By P. M. Delacharlonny (*Comptes Rendus*, **103**, 1,128).—When strong solutions of sodium hydroxide, sodium carbonate and ferric sulphate are heated to 65–70° in vessels covered with inverted funnels, some of the dissolved substance is carried off with the vapor, as may be proved by appropriate test papers placed in the apices of the funnels. The test papers are colored after four or five days, even at ordinary temperatures, and that the solid is not carried off as such in particles is proved by the fact that the test papers become uniformly colored and not in streaks or patches. Acid solutions of alum and of ferric sulphate give similar results at ordinary temperatures. W. H. G.

TOXIC PROPERTIES OF METALS.—These properties are in proportion to the atomic weight and the specific heat of the metal. The theory may be expressed thus: The higher the atomic weight and the lower the specific heat, the more intense is the metallic poison. Lithium furnishes an exception to this law of toxicity of metals; but metallic lithium kills by its convulsing action on the nervous system, and not by the ordinary toxic effect of metals, which is that of destruction of the functional activity of the nervous system. R. L. B.

PHYSIOLOGICAL ACTION OF INSOLUBLE REAGENTS.—In a report of experiments given in *The Journal of Physiology*, **6**, No. 3, by Dr. James Blake, of San Francisco, it is stated that recently precipitated ferric oxide Fe_2O_3, injected into the veins of an animal in small quantities proved instantly fatal; precipitated alumina, Al_2O_3 caused death after a second injection. Barium

sulphate furnished a negative result, the insoluble sulphate producing no effect.

A microscopical examination of the precipitates explained the difference in their physiological action; the aluminium and the ferric oxides were in flakes; the particles of the barium sulphate were thirty times less in size. The Al_2O_3 and Fe_2O_3 would thus prove fatal by causing embolism in the pulmonary capillaries. R. L. B.

THE MAGNESIUM FLASH-LIGHT FOR PHOTOGRAPHIC PURPOSES, as might have been anticipated, has rapidly acquired popularity, but despite words of caution, and in open disregard or ignorance of well-established chemical facts, mixtures of a highly dangerous character have been proposed, and some have been brought into the market; and an explosion in the preparation of such a mixture, of which chlorate of potash and picric acid were ingredients, resulted fatally to the workman. Whilst ignition by means of gun-cotton, previously given, is without danger, a method proposed by Mr. Bishop, before the North London Photographic Society, may be more convenient or comfortable in some cases, whilst it is said to be equally effective. In it the magnesium powder is simply blown into the flame of a spirit lamp supplied with two wicks, one about three inches in front of the other, so that the powder that escapes combustion in the first may be ignited by the other. The magnesium powder is contained in a small wide-mouthed bottle, with two tubes passing through the cork; through one, which dips beneath the powder, the magnesium is suddenly projected into the flame by pressure upon a pneumatic ball attached to the other, which only extends below the cork. The amount of powder delivered to the lamp is easily regulated, and the operation can be repeated until the bottle is emptied. C. F. H.

PHYSICS.

A NOVEL ELECTRO-MAGNET.—Maj. Wm. R. King, of the U.S. Corps of Engineers, has frequently had occasion to exercise his ingenuity in inventing new devices in connection with his military and civil operations.

Since his late transfer to the command of the Engineer School of Application at Willits Point, N. Y., he has been engaged in making some interesting experiments in electro-magnetism on a large scale and with unusual materials.

Two fifteen-inch "columbiads," weighing 50,000 pounds each, were mounted side by side with their axes parallel. Their muzzles were then wound with about eight miles of insulated wire extending over a length of six feet, and the breeches were connected by lashing ordinary railroad rails across them. The net section of this part of the magnet being only about sixty square inches was much too small for the best results; the armature used was also too light, having a section of but eighty-two square inches.

The current was generated by a thirty horse-power dynamo, and the following results were obtained. A pull on the dynamometer chain attached to one end of the armature, detached it, with an indicated tension equivalent to 20,600 pounds if applied at the centre.

It sustained four fifteen-inch shells weighing 320 pounds each, or 1,280 pounds in all, suspended from the muzzle of one of the guns.

The magnetic field was so large that by holding a spike or piece of iron in the hand it was possible to perceive the lines of force even at a distance of from five to six feet and to indicate the curves of their relative directions on paper. By this means a neutral point was found in the axis of the bore of each gun seven and one-half inches in front of the muzzle. Between this point and the gun there was a strong repulsion, while beyond it the attractive forces preponderated.

By placing small pieces of soft iron wire in the axis of the gun they would be shot out about two feet, when the opposite current would draw them suddenly back to the rim of the bore where they would remain fast until the current was broken.

These experiments are of interest as illustrating how even very crude apparatus may be made to contribute to the general fund of scientific knowledge when assembled and directed by a skilful operator. The full strength of the magnet was not developed, in consequence of lack of sufficient materials to properly proportion the several parts. It revives the active interest which was created by the powerful magnets constructed by the illustrious Dr. Joseph Henry, who, when Professor of Physics, at Princeton, about 1831, made a magnet which supported 3,600 pounds by a current from a small electrical battery, "not more than a foot square." This machine is believed to be still a part of the apparatus of Princeton College. It was through these discoveries of Prof. Henry that the electric telegraph became an accomplished fact in 1844. L. M. H.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, February 15, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, February 15, 1888.

JOSEPH M. WILSON, President, in the Chair.

Present, 101 members and eleven visitors.

Accessions to membership since last meeting, twelve.

Prof. SAM'L P. SADTLER was elected to the Board of Managers, in place of Mr. W. P. Tatham, whose election to the position of Vice-President at the last annual election caused a vacancy.

Prof. LEWIS M. HAUPT, of the University of Pennsylvania, by invitation, made an address in which he dwelt upon the important and intimate relations existing between the growth of a great city and the development of its means for promoting external and interior traffic, drawing his illustrations from the experiences of London and New York. He explained, in conclusion, the plan of an underground railway proposed for the City of Philadelphia.

Mr. Fred. E. Ives made some further remarks upon the "Japanese Magic Mirror," in the course of which he stated that he had learned from Prof. Wm. A. Anthony, since the publication of his remarks at a previous meeting, that he had been anticipated in the explanation he had offered to account for the production of the magic image, by M. Dubosq, the well-known maker of philosophical apparatus, in Paris.

The Secretary exhibited, in the course of his report, a suite of interesting specimens of electric-welding, presented to the Institute by the Thomson Electric-Welding Company, of Lynn, Mass.

The Secretary exhibited also a series of fine and elaborately-decorated articles of solid silver, made by electro-deposition. The makers were Messrs. Thomas G. Brown & Sons, of Newark, N. J.

The President announced the appointment of the following, to constitute the Standing Committees of the Institute for the current year, viz.:

STANDING COMMITTEES OF THE FRANKLIN INSTITUTE FOR THE YEAR 1888.

Library.	*Minerals.*	*Models.*
Charles Bullock,	Clarence S. Bement,	Edward Brown,
J. Howard Gibson,	Persifor Frazer,	John H. Cooper,
Frederick Graff,	F. A. Genth,	C. Chabot,
Geo. A. Koenig,	Edwin J. Houston,	L. L. Cheney,
S. H. Needles,	George A. Koenig,	N. H. Edgerton,
Isaac Norris, Jr.,	Otto Lüthy,	John Goehring,
John C. Trautwine, Jr.,	E. F. Moody,	Morris L. Orum,
Chas. E. Ronaldson,	H. Pemberton, Jr.,	Chas. Richardson,
Wm. P. Tatham,	Theo. D. Rand,	John J. Weaver,
Lewis S. Ware.	Wm. H. Wahl.	S. Lloyd Wiegand.

Arts and Manufactures.	*Meteorology.*	*Meetings.*
J. Sellers Bancroft,	Lorin Blodget,	Hugo Bilgram,
George Burnham,	Charles M. Cresson,	Geo. V. Cresson,
Cyrus Chambers, Jr.,	Edwin J. Houston,	G. M. Eldridge,
Wm. Helme,	Isaac Norris, Jr.,	Fred'k Graff,
Wm. B. Le Van,	Alex. E. Outerbridge, Jr.,	Henry R. Heyl,
Alfred Mellor,	J. S. W. Phillips,	Washington Jones,
C. C. Newton,	M. B. Snyder,	Sam'l R. Marshall,
Henry Pemberton,	Wm. P. Tatham,	G. H. Perkins,
E. Alex. Scott,	N. Wiley Thomas,	Chas. E. Ronaldson,
Wm. Vollmer.	Wm. H. Wahl.	Wm. H. Thorne.

Adjourned. Wm. H. Wahl, *Secretary.*

PILOT CHART OF THE NORTH ATLAN[TIC]

100 90 80° 70 60° 50° 40°

NOTICES TO MARINERS ISSUED DURING THE MONTH OF FEBRUARY, 1888

Any of the Notices to Mariners published by the Hydrographic Office will be sent, free of charge, on application to the Hydrographer. In making applications, designate the notices required by the numbers given in the left margin. The smaller figures to the right show the number of the paragraph. Files are kept at the Branch Hydrographic Offices and are open to examination.

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Dangerous Obstructions to Navigation along the Coast.

NOTE.—This list is compiled from all available data, and is corrected up to the hour of going to press. Reports as to the continued existence or the removal of any of these obstructions are specially requested from masters of vessels passing in their vicinity.

Latitude 44° 46′ N., longitude 60° 22′ W.: Vessel's mast 8 feet out of water. Reported November 10.

Cape Elizabeth west, 8 miles: Sunken schooner; masts out of water. Reported January 2.

Sankaty light, North 12 miles: A wreck in 11 fathoms. Last reported August 28.

Monomoy point light NW. by N., ½ mile: Sunken schooner; mast-heads out of water. Reported December 22.

Nantucket New South shoal light-ship NNW., 4 miles: Sunken steamer Newcastle City in 15 fathoms water; masts from 6 to 8 feet above water; a dangerous obstruction. Reported January 10.

Bishop and Clerk's light NW. by W., 5 miles: Sunken schooner Panope, in 6 fathoms; topmasts above water; buoyed. Reported February 15.

Jedith point: Schooner Mary A. Drury; hull still holds together; spars standing. Last reported January 10.

Falkner's island, NE. by E.; Branford reef beacon, NW. ¾ N.: Sunken schooner Helen Augusta; mast 4 feet above water. Reported January 13.

Gull island light, ESE.: Bartlett's reef light, N.: Sunken schooner Wm. M. McKay. Reported February 6.

Shinnecock light WNW. ¾ W., 4 miles: Sunken schooner. Reported December 21.

Off Barnegat: Schooner "Lizzie Wilson." Sunk August 18.

Barnegat N. ¾ W., 5 miles: A sunken wreck in 9 fathoms of water. Reported December 22.

Barnegat light-house SW. by S., 12¼ miles: Pilot-boat Francis Perkins in 11 fathoms of water; masts broken off 3 fathoms under water. Last reported September 16.

Barnegat NW. by W. ¾ W., 9 miles: Sunken wreck; one mast out of water. Last reported October 3.

Tucker's beach light-house W. ¾ N., 11 miles: Sunken schooner Nellie S. Jerrell. Located December 13.

Tucker's beach light-house W. by N., 8 miles: Schooner Marietta Steelman. Reported to be breaking up October 11. Also, about 1,000 feet N. by W. from this wreck, steamer E. C. Knight. Last reported October 17.

Absecum NW., 20 miles: Sunken schooner Katie Ranger. Foundered December 18; position uncertain.

Absecum light West, 8 miles: Sunken schooner; one mast 10 feet above water. Reported February 1.

Absecum NNW., 33 miles: Sunken schooner; masts 15 feet above water. Reported February 13.

Fenwick's island light NW., 27 miles: Vessel; mast 30 feet above water; rigging attached. Reported December 17.

Winter Quarter shoal light-ship NW. ¾ N.: Sunken vessel, in 24 fathoms; one topmast 6 feet above water. Reported February [ ].

Cape Henry light South, 4½ miles: Sunken schooner E. B. Everman, in 7½ fathoms; buoyed. Last reported December 28.

Lambert's point light-house ENE. ¾ E.: Coal barge Marion sunk in mid-channel; a white light at night. Reported December 28.

Currituck NW., 20 miles: Sunken bark Samuel Welsh. Reported February 25.

Hatteras light W. by N.: Sunken schooner, in 7 fathoms; two masts above water. Reported February 21.

Charts published during the month of February, 1888.

1056. St. Pierre, Miquelon Islands.
1092. Galet Anchorage, Desirade Island, West Indies.

CHARTS CANCELED.

326a. Virgin Islands, Eastern Sheet, with plans of Santa Cruz, Christiansted Harbor, Santa Cruz.
031. Todos Santos Bay and vicinity.
Plan of Port du Moule on Chart 38[ ].
Plan of Port Louis Anchorage on Chart 531.

BAROMETER COMPARISONS.

The attention of masters of vessels is called to the importance of having their barometers compared with Standards as often as possible, as the practical value of weather indications furnished by the barometer depends very largely upon the amount it reads above or below the normal at the ship's position, given for each 5° ocean square in the table accompanying the weather review on this Chart. Unless the barometer has been recently compared with a Standard instrument, however, and its exact error obtained, no practical use can be made of this table of barometer normals, nor are such observations of nearly as great value to the Hydrographic Office.

Through the courtesy of Professor Charles Carpmael, Superintendent of the Meteorological Service of Canada, arrangements have been made by which every facility for making such comparisons can be obtained at the following ports in the Dominion of Canada, and communications may be sent to the addresses stated:

NOVA SCOTIA.—Halifax: Augustus Allison; Sydney, C. B.: Thomas C. Hill. Yarmouth: Captain J. E. Murphy.

NEW BRUNSWICK.—Chatham: D. T. Johnston, Jr., Esq. St. Andrews: S. T. Gove. St. John: George Hutchinson, Observatory.

PROVINCE OF QUEBEC.—Montreal: C. H. McLeod, McGill College Observatory. Quebec: W. A. Ashe, Observatory.

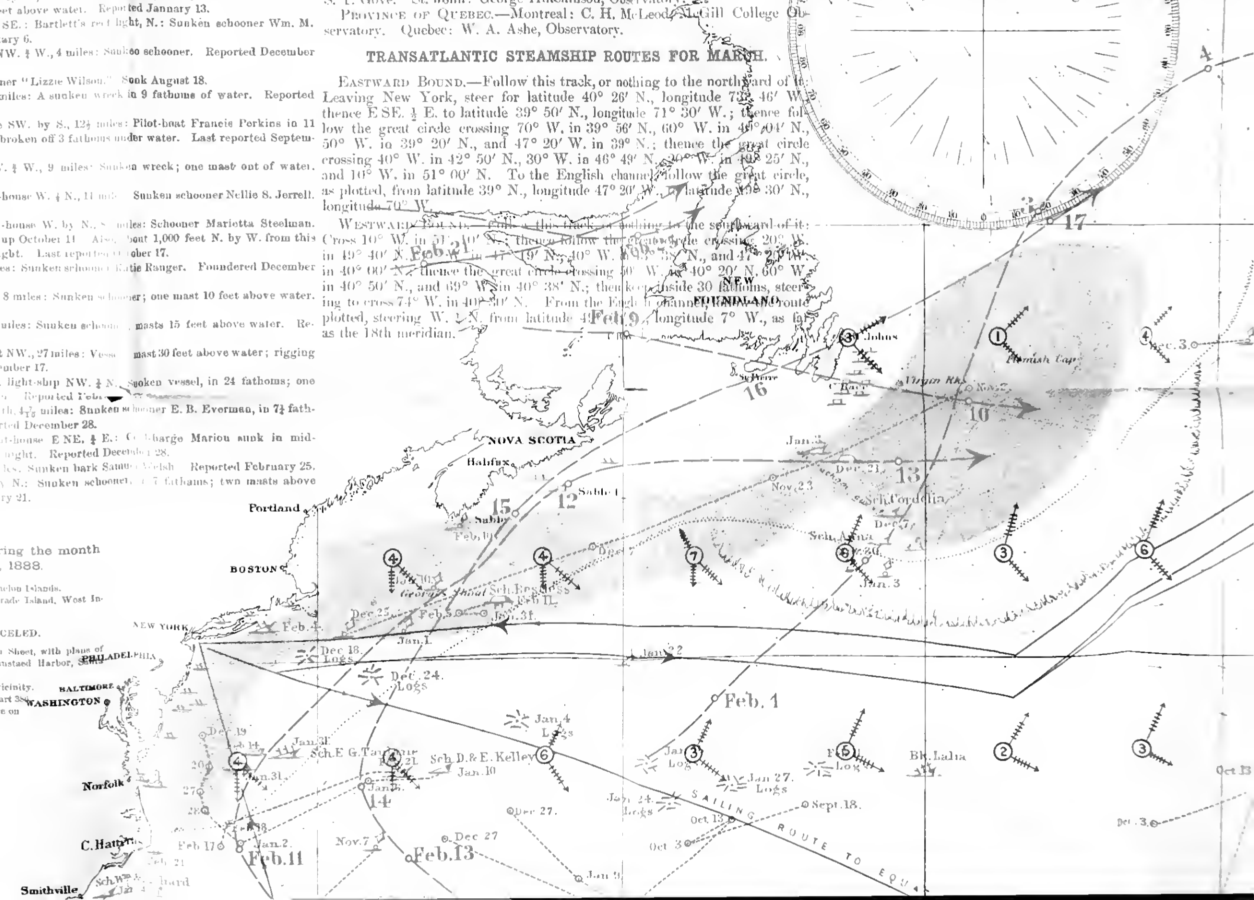
TRANSATLANTIC STEAMSHIP ROUTES FOR MARCH.

EASTWARD BOUND.—Follow this track, or nothing to the northward of it: Leaving New York, steer for latitude 40° 26′ N., longitude 73° 46′ W.; thence ESE. ½ E. to latitude 39° 50′ N., longitude 71° 30′ W.; thence follow the great circle crossing 70° W. in 39° 56′ N., 60° W. in 40° 04′ N., 50° W. in 39° 20′ N., and 47° 20′ W. in 39° N.; thence the great circle crossing 40° W. in 42° 50′ N., 30° W. in 46° 49′ N., 20° W. in 49° 25′ N., and 10° W. in 51° 00′ N. To the English channel follow the great circle, as plotted, from latitude 39° N., longitude 47° 20′ W., to latitude 49° 30′ N., longitude 70° W.

WESTWARD BOUND.—Follow this track, or nothing to the southward of it: Cross 10° W. in 51° 10′ N.; thence follow the great circle crossing 20° W. in 49° 40′ N., 30° W. in 47° 19′ N., 40° W. in 43° 38′ N., and 47° 20′ W. in 40° 00′ N.; thence the great circle crossing 50° W. in 40° 20′ N., 60° W. in 40° 50′ N., and 69° W. in 40° 38′ N.; then keep inside 30 fathoms, steering to cross 74° W. in 40° 30′ N. From the English channel, follow the route plotted, steering W. ½ N. from latitude 49° [ ], longitude 7° W., as far as the 18th meridian.

THE LOGS OF THE GREAT RAFT.

Although nearly two and one-half months have passed since the gr[eat] raft was abandoned south of Nantucket, reports continue to be receiv[ed] from vessels falling in with the logs, which are now widely separat[ed]. The general drift has been in an ESE. direction, the logs being fo[und] a little to the southward of this line. That they were not carried m[ore] to the northward and eastward by the Gulf stream, as would be expect[ed], was probably due to the strong NW. winds which prevailed during [the] latter part of December and the first part of January. Fortunately [no] vessel has been disabled by collision with them, although the Germ[an] bark "Bremen," which was in company with the logs for 5 days, [in] latitude 39° 00′ N., longitude 62° 00′ W., had her sheathing torn a[nd] rudder injured. The latest reports of the logs having been seen are [as] follows: British steamer "Hampshire," January [ ], in latitude 36° [ ] N., longitude 58° 36′ W.; British steamer "Pictou," January 27, [in] latitude 36° 40′ N., longitude 56° 25′ W.; German bark "Marie" w[as] amongst the logs for several days, January 9 to 13, about latitude 3[ ] N., longitude 50° to 60° W.; and the British steamer "Empire," Fe[b]ruary 22 and 23, in latitude 37° N., longitude 59° to 6[ ] W.



OF THE NORTH ATLANTIC OCEAN

MARCH, 1888.

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FOR MARCH.

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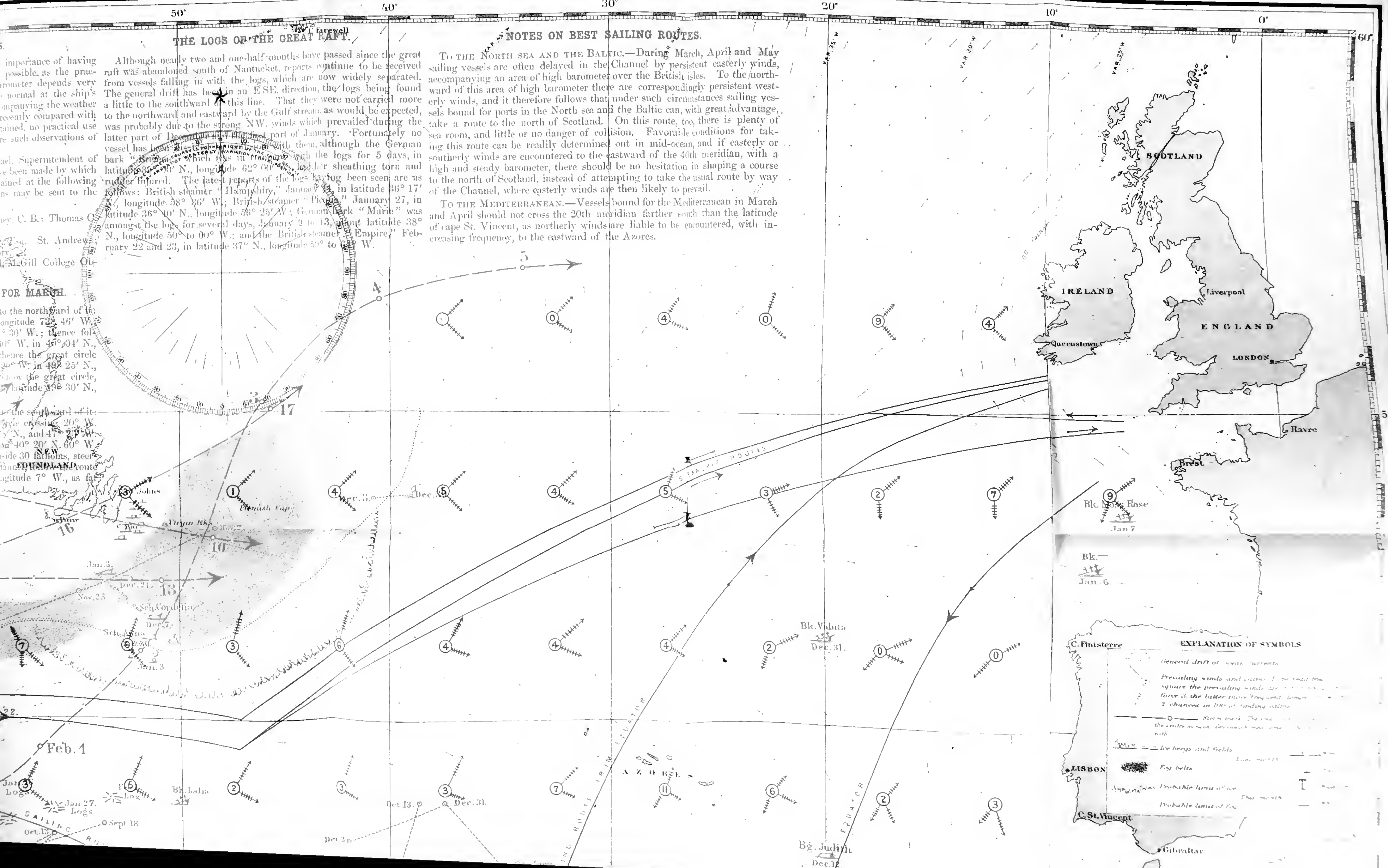
THE LOGS OF THE GREAT RAFT.

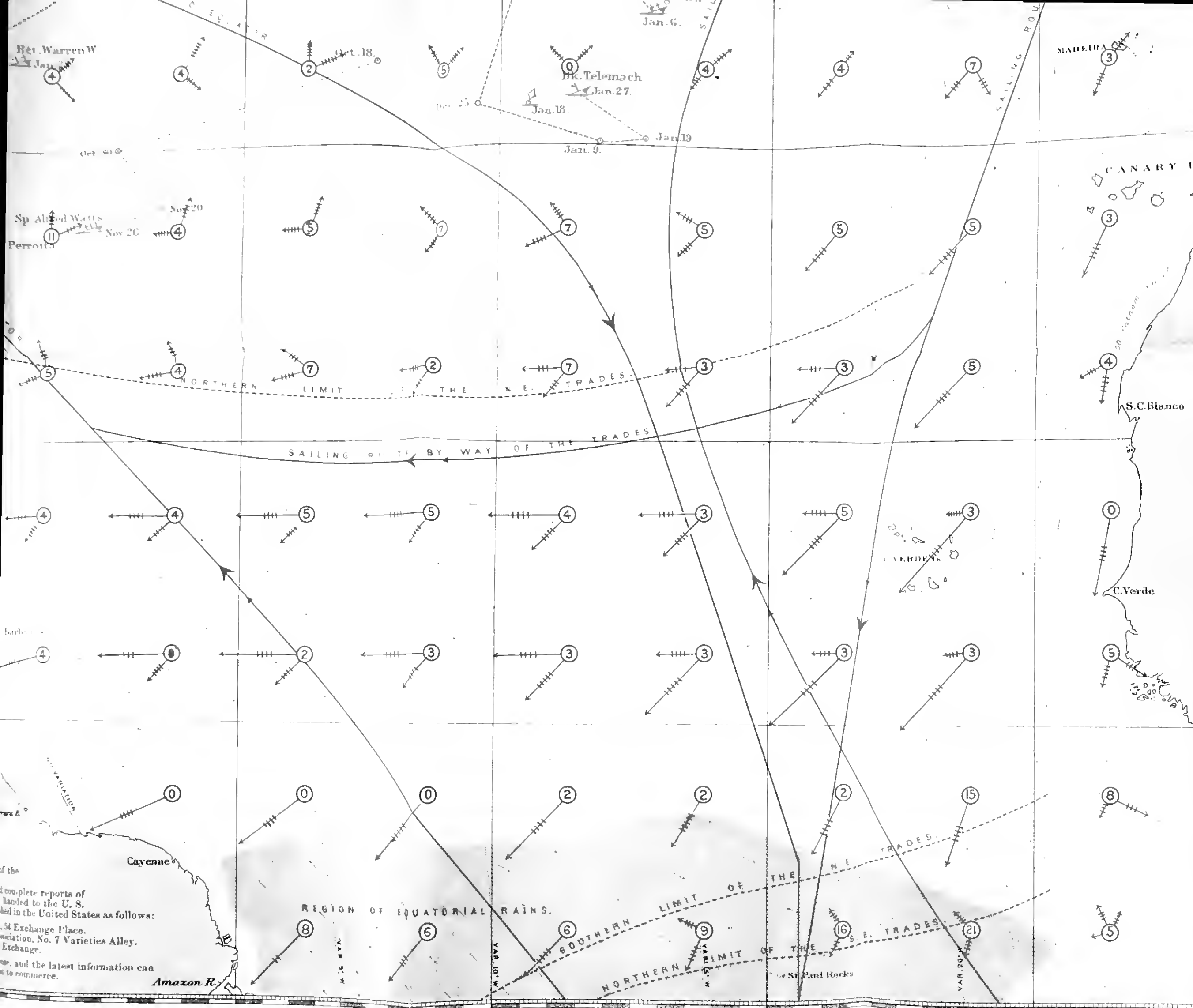
Although nearly two and one-half months have passed since the great raft was abandoned south of Nantucket, reports continue to be received from vessels falling in with the logs, which are now widely separated. The general drift has been in an ESE. direction, the logs being found a little to the southward of this line. That they were not carried more to the northward and eastward by the Gulf stream, as would be expected, was probably due to the strong NW. winds which prevailed during the latter part of December and the first part of January. Fortunately no vessel has been disabled by collision with them, although the German bark "[illegible]" which was in latitude 3[illegible]° [illegible]0′ N., longitude 62° 00′ W., was with the logs for 5 days, and had her sheathing torn and rudder injured. The latest reports of the logs having been seen are as follows: British steamer "Hampshire," January 24, in latitude 36° 17′ N., longitude 58° 36′ W.; British steamer "Pictou," January 27, in latitude 36° 40′ N., longitude 56° 25′ W.; German bark "Marie" was amongst the logs for several days, January 9 to 13, about latitude 38° N., longitude 50° to 60° W.; and the British steamer "Empire," February 22 and 23, in latitude 37° N., longitude 59° to 60° W.

NOTES ON BEST SAILING ROUTES.

To the North sea and the Baltic.—During March, April and May sailing vessels are often delayed in the Channel by persistent easterly winds, accompanying an area of high barometer over the British isles. To the northward of this area of high barometer there are correspondingly persistent westerly winds, and it therefore follows that under such circumstances sailing vessels bound for ports in the North sea and the Baltic can, with great advantage, take a route to the north of Scotland. On this route, too, there is plenty of sea room, and little or no danger of collision. Favorable conditions for taking this route can be readily determined out in mid-ocean, and if easterly or southerly winds are encountered to the eastward of the 40th meridian, with a high and steady barometer, there should be no hesitation in shaping a course to the north of Scotland, instead of attempting to take the usual ronte by way of the Channel, where easterly winds are then likely to prevail.

To the Mediterranean.—Vessels bound for the Mediterranean in March and April should not cross the 20th meridian farther south than the latitude of cape St. Vincent, as northerly winds are liable to be encountered, with increasing frequency, to the eastward of the Azores.





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...during February, the southern limit of frequent gales being in general, a line from Hatteras to the English channel. To the northward, gales may occur as often as once in six days, blowing hardest from southwest and northwest, and frequently attended by electrical phenomena. Along the coast of the United States from Hatteras southward, the winds will be variable. Northers will be less frequent in the Gulf; they will, however, be heavier for the few days and have less northwesting. The northeast trades will be somewhat stronger than last month. Icebergs and field-ice will be encountered as far south as the 40th parallel, between 41° and 55° W. longitude as indicated by the probable ice limit on the Chart. Fog will be encountered with increasing frequency off the Grand banks and the coast to the westward.

BAROMETER NORMALS—MARCH.

These normals, with the exception of those for ocean squares in the Caribbean sea and south of the 10th parallel, have been computed from the simultaneous meteorological observations taken by international co-operation and published by the U. S. Signal Service. They are based on from seven to nine years' observations, and have been specially prepared by the Chief Signal Officer, U. S. Army, for the use of the Pilot Chart, in advance of their regular publication. To complete the table, figures have been added from other reliable data.

LONGITUDE.

LATITUDE.	100°		90°		80°		70°		60°		50°		40°		30°		20°	
60°											29.64	29.67	29.64	[illegible]	29.74	29.77	[illegible]	[illegible]
											29.77	29.76	29.73	29.81	29.85	29.88	29.85	29.90
50°											29.80	29.83	29.85	29.89	29.92	29.94	29.97	[illegible]
							29.24	29.69	29.88	29.66	29.91	29.95	29.94	30.02	30.04	[illegible]	30.02	30.41
40°						30.01	29.98	29.94	29.94	29.97	29.99	30.03	30.06	30.13	30.15	30.14	30.10	30.06
					30.08	30.06	30.04	30.03	30.02	30.04	30.07	30.11	30.14	30.17	30.17	30.16	30.12	30.10
30°	30.03	30.05	30.07	30.09	30.11	30.11	30.11	30.10	30.09	30.11	30.13	30.16	30.17	30.17	30.17	30.15		
	30.02	30.04	30.07	30.06	30.08	30.11	30.11	30.12	30.11	30.11	30.12	30.14	30.15	30.12	30.13	30.10		
20°			30.02	30.02	30.04	30.04	30.05	30.03	30.07	30.07	30.10	30.09	30.08	30.08	30.06	30.06		
				29.95	29.96	29.99	30.00	30.00	29.99	30.04	30.06	30.05	30.06	30.04	30.03	30.01		
10°									29.97	29.97	29.97	29.97	29.97	29.97	29.97	29.90	29.92	
											29.93	29.93	29.93	29.93	29.92	29.92	29.92	29.92

To correct the observed reading of a vessel's barometer, in order to compare it with the normal given in the above table, apply first the error shown by last comparison with standard, subtracting this error if high, adding if low. Then, if mercurial, subtract a small correction depending on the reading of the attached thermometer, as follows: Attached thermometer, 40°, correction, .03; 50°, .06; 60°, .08; 70°, .11.

Review of February.—Fresh westerly winds have prevailed over the transatlantic steamship routes during the greater part of the month, and a cyclonic disturbance of considerable severity was central on the 1st in about 39° N. and 57° W., moving northeasterly. It crossed the Grand banks on the 2d, and on the 3d, 4th and 5th moved eastward about the 54th parallel; the lowest corrected barometer reading reported was 28.47, and the highest force of wind 11, of Beaufort's scale. This storm was accompanied by strong gales as far south as the 30th parallel, with heavy snow, hail, and sleet along the transatlantic steamship routes. On the morning of the 9th an area of low pressure, which had advanced from the continent, was central over the eastern portion of the gulf of St. Lawrence, and by the 10th it had passed eastward over Newfoundland. Two cyclonic storms passed in close succession along the Atlantic coast of the United States towards Newfoundland. Both seem to have originated in the vicinity of the Bermudas, and to have lost considerable energy after passing the 40th parallel, north of which no report has been received of a higher force of wind than 9. The first of these was central about 120 miles east from Hatteras on the 11th, and it is interesting to note that large waterspouts were reported by vessels in the southwest quadrant of this storm on the 10th and 11th. The second was central about 300 miles east from Hatteras on the 13th, whence it moved on the usual parabolic track to the northward and then to the northeastward, crossing southern Newfoundland on the 16th, and disappearing north of the 50th parallel. A storm of highest force of wind 10 was central at the mouth of the St. Lawrence river on the 21st, moving thence over the straits of Belle Isle.

Two marked depressions crossed the gulf of Mexico, one in the western part on the 2d, the other in the center on the 23d. The latter traversed the United States to the Great Lakes and was central in the gulf of St. Lawrence on the 25th. But one norther was felt in the gulf.

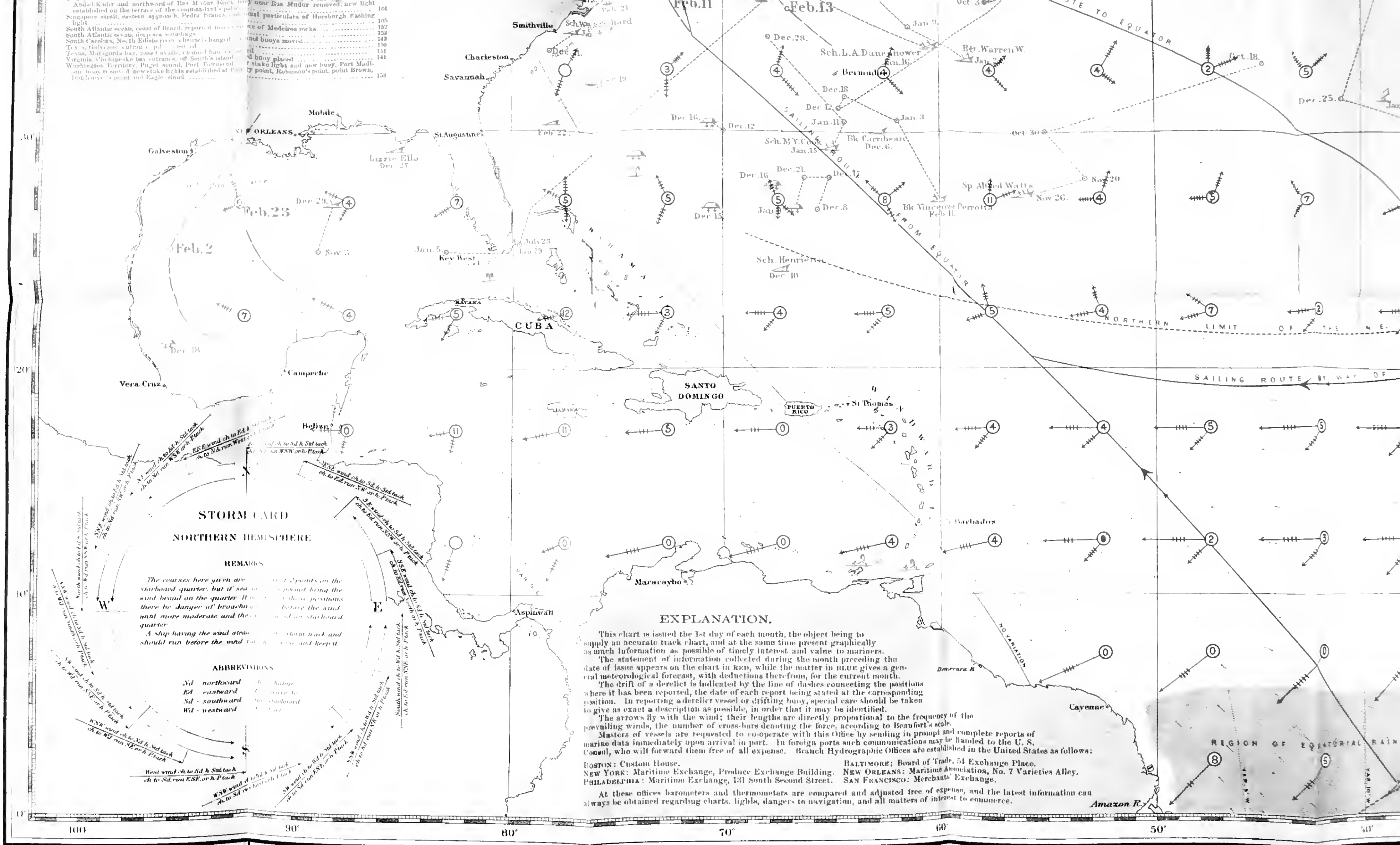
Over the British isles barometric pressure was generally high until the 10th, from which date unsettled weather and low and fluctuating barometer continued until after the 13th. From the 14th to the 18th, inclusive, the barometer was high east of the 30th meridian.

Incoming steamers report very mild weather during the latter part of the month.

More fog has been experienced off the Grand banks and along the Atlantic coast of the United States than is usual during February, owing to the frequent depressions that moved through those regions during the month. These depressions, in the eastern quadrants of their areas, cause strong southerly winds, which bring the warm, moist air from over the Gulf stream into contact with the colder atmosphere to the northward, thus lowering the temperature of the former below the dew-point and precipitating its moisture as fog. In the vicinity of the British isles, however, where high barometric pressure has prevailed, but little fog has been noticed.

Ice has begun to descend, reports having been received of large fields between 50° W. and 63° W., and as far south as 44° N.

Published Monthly at the Hydrographic Office, Navy Department Washington, D. C.
J. R. Bartlett, Commander, U. S. N., Hydrographer to the Bureau of Navigation.



Division of Marine Meteorology, Everett Hayden.

Published Monthly at the Hydrographic Office, Navy Department, Washington D.C.
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JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

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THE PILOT CHART OF THE NORTH ATLANTIC OCEAN,

ISSUED MONTHLY BY THE UNITED STATES HYDROGRAPHIC OFFICE.*

BY EVERETT HAYDEN, in charge of the Division of Marine Meteorology, United States Hydrographic Office.

[*A Lecture delivered before* THE FRANKLIN INSTITUTE, *Friday, January 27, 1888.*]

MR. HAYDEN was introduced by the Secretary of the INSTITUTE, and spoke as follows:

Ladies and Gentlemen, Members of the INSTITUTE:—The pilot chart, which I have the honor to describe to you this evening, is very different in character from all other charts with which the

*This lecture was illustrated by twenty-four lantern slides, and such illustration is very essential to clearness. Through the courtesy of the hydrographer, Commander J. R. Bartlett, U. S. N., we are enabled to issue a copy of the chart itself, however, which will give great assistance to the reader. W.

navigator has to deal. It is, I may say, a *composite* chart; that is, an ordinary track chart, with the addition of a great deal of timely, interesting and useful data, which do not appear on any other chart. The object is, first, to supply a reliable chart upon which to plot a vessel's track after getting clear of the coast (where, of course, more detailed and larger scale charts are used); and, secondly, to present graphically any information relating to the North Atlantic of interest and value to mariners during each month of the year. It would require far more time than I have at my disposal this evening thoroughly to illustrate how this is accomplished month after month and year after year, and I shall only attempt to describe a single edition of the Pilot Chart, the one for January, 1888.* In doing so, I propose to follow first the synthetic method, starting with the outline, or base chart, and adding other data, just as is done in the actual publication of the chart. This will, I think, make the subject far clearer to an audience, most of whom, I take it, are not familiar with all the technical details relating to charts and navigation. Then, after having briefly described the general character of the chart and the different kinds of data which are published on it, I shall make a hasty and necessarily somewhat superficial analysis of the chart, discussing successively such features as may seem most interesting and instructive.

To begin with, I will show you the base of the Pilot Chart, which is simply a track chart of the North Atlantic on Mercator's Projection.† This comprises what may be called the permanent portion of the chart, or the portion which does not change from month to month, but is the same each month of the year. This is lithographed in black by means of a transfer from a copper plate. Near the top you will notice the compass card, which the navigator uses to lay off his course. In the lower left-hand corner is a storm card (Northern Hemisphere), which illustrates the circulation of the wind around an area of low barometer, with brief practical rules for action to avoid the dangerous portions of an approaching cyclone. At the right-hand side is given an

* Although the January chart was described in the lecture, the chart for March is published herewith, necessitating certain slight changes in the lecture itself, as printed.

† To follow the text, refer to the Pilot Chart, published herewith, considering first what is printed in *black*, then in *blue*, and finally in *red*.

explanation of symbols. The symbols which are thus explained are those used in plotting other data on this base, as will be explained in a few moments. The light curved lines which cross the chart are variation curves; that is, curves showing the variation of the magnetic compass. You will notice, also, the very light dotted line near the coast: that is the 100-fathom curve. The small arrows, which, indeed, are so very fine on the original chart as to hardly show when reduced to the very small size required for use with a lantern, indicate the general drift of ocean currents. Although these currents vary considerably during the year, it is only safe to indicate their general direction or average for the entire year; to attempt to do more would merely lead to error. Without speaking further at present of this outline or base chart, I will take up next what are called the "blue data." I will say here, by the way, that in order to avoid confusion, and to make the chart as clear as possible in spite of all that is printed upon it, two colors are used for the second and third impressions, respectively—blue and red. Practical difficulties make it impossible to show on this screen the base chart and the blue and red data just as they appear on the chart itself, superposed one upon the other, and I shall therefore be obliged to illustrate each separately from the base chart.

The blue data consist essentially of a meteorological forecast for the month following the date of issue, and in addition to this forecast there are plotted the principal steamship and sailing routes recommended for the month. The small circles and arrows which you see plotted uniformly over the ocean indicate graphically the probable percentage of calms, and the frequency and force of the prevailing winds in each five-degree ocean square. There being no fixed meteorological stations on the high seas, it is necessary to group together observations made on board vessels in some way by which they can be localized and averaged up; this is done by dividing up the ocean into squares bounded by five degrees of latitude and longitude, and every vessel which goes through one of these squares and keeps meteorological observations adds just so much to our knowledge of the prevailing weather conditions in that square. It therefore happens that there are many squares whose meteorological conditions are very well-known, on account of the very great number of vessels which

traverse them; while, on the contrary, there are other squares, which lie off the tracks of commerce, whose meteorological conditions are only approximately known. To repeat, therefore, the figures in the circles in each five-degree ocean square indicate the percentage of calms likely to be met with; the arrows fly with the wind and indicate by their length the relative frequency of prevailing winds, and by the number of cross-bars the force of the wind according to Beaufort's scale. This scale of wind force is a scale in general use among mariners for recording the force of the wind. It varies from 0 (a calm) to 12 (a hurricane); and though necessarily somewhat rough—the force of wind being estimated largely from the amount of sail a full-rigged ship can carry—yet from long practical usage it has become tolerably definite and accurate, and the figures of the Beaufort scale give a sailor an instant and vivid idea of the force of wind experienced. In addition to this graphic representation of the frequency and force of prevailing winds in each ocean square, there is printed a brief forecast and a table showing the normal reading of the barometer, arranged in tabular form by ocean squares. The double dotted line which you see up towards Newfoundland is the probable limit of the region of frequent fogs for the coming month. The dotted lines across the lower portions of the chart indicate the limits of the trade winds; that is, both limits of the northeast trades, and the northern limit of the southeast trades, the other limit of the southeast trades being south of the equator, and not appearing on this chart. Where these northeast and southeast trades meet there is the region of equatorial rains, indicated by the blue belt of irregular shape lying principally to the northward of the equator.

With this brief glance at the blue data, I will now refer briefly to the red data. In a general way it may be said that the red data comprise information collected during the month preceding the date of issue. On the ocean there are plotted the latest reported positions of derelict vessels, wrecks, and drifting buoys. The dotted line, where there is a dotted line, indicates the drift which each wreck has followed since it was first reported. There are also plotted the positions where whales and water-spouts were reported during the previous month, and the red belt off Newfoundland indicates the region where frequent fogs were encountered. In the lower right-hand corner is printed a brief weather

review of the preceding month, written at the last moment before going to press, but necessarily more or less incomplete, so far as the entire Atlantic is concerned. Above, there is, as you will notice, a large amount of printed matter, comprising a list of notices to mariners issued during the previous month, dangerous obstructions to navigation along the coast, charts published and cancelled, transatlantic steamship and sailing routes, the latest reported positions of logs from the big lumber raft which was abandoned off Nantucket, and various other matter likely to be of timely interest. To one who is not familiar with the subject it will seem almost impossible to publish on one chart such a variety of information of such a diverse character, and yet have a chart that can be of practical use in plotting a vessel's track. It would be very difficult to do so without this distinction of colors, and yet it has been done, to a certain extent, in the preparation of what is called the "Abstract" of the Pilot Chart, a reduced copy printed entirely in black expressly for the use of the *New York Herald*, *Boston Post*, and certain other papers which devote special attention to the interests of commerce, in order that they may publish it, reduced in size, in their regular edition the first day of each month. This being, as I have said, entirely in black and white, can be illustrated entire on the screen, and while it by no means comprises all the data published on the regular edition of the Pilot Chart, yet it serves as a very good illustration of the general effect of the chart with all the data printed on one sheet. For the sake of clearness it is here necessary to omit many things, the tracks of derelict vessels for instance, the arrows showing the general drift of ocean currents, the 100-fathom curve, storm card, regions of frequent fog, all the printed matter, etc.; still, the leading features of the chart are given very clearly and graphically.

To illustrate still better the amount of data which the regular edition contains, I have had a copy printed entirely in black, and it may be of interest to see just what it looks like printed in this way.*

Having made this brief and hasty synthesis of the chart, I will take up certain points in greater detail, and endeavor to analyze and discuss them at greater length. In the first place, let us resume

* This was illustrated on the screen and discussed, but need not be referred to further here.

our consideration of the track chart which serves as the base upon which the Pilot Chart, as it is finally issued, is built up. This chart is on what is known as "Mercator's Projection," devised by a celebrated Dutch geographer and mathematician named Kauffman (in Latin, Mercator). It has been in use among navigators, since the middle of the sixteenth century and still holds the foremost place as a practical working chart, in spite of all the improvements and refinements which three centuries of progress have suggested. There are some who think that it is a pity that such is the case, and that there are other and better projections which sailors ought to use in preference to the Mercator; nevertheless, the fact that this projection has held its own, and is now almost universally preferred, must undoubtedly be regarded as showing that the practical advantages which it possesses for use aboard ship are more than enough to counter-balance whatever theoretical objections may be urged against it. The great feature of a Mercator chart is, that the track of a ship steering a true course, describing the well-known loxodromic curve on the surface of the sphere, is here plotted as a *straight line*, and the true course to be steered in order to reach a given port may be taken directly from the chart. One of the principal *objections* to a Mercator chart is, that a great circle course, the shortest distance between any two points on a sphere, is represented on this chart by a *curved* line in every case except when a vessel is moving east or west on the equator itself, or when steering due north or south. To illustrate this, I will show you what is called a *gnomonic* chart, upon which a *great circle* is a *straight line*, while a *true course* is a *curved line*. The Mercator chart may be described as a projection of the surface of the sphere on a cylinder tangent to the earth at the equator. Although this is not strictly true, yet it is sufficiently close to the truth not to involve any appreciable error for our present purposes. A gnomonic chart, however, is a projection of the surface of the sphere on a plane tangent to the sphere—in this case, tangent at the intersection of the 30th meridian and the equator. Now, anyone can see that it is impossible to represent a curved surface on a plane surface without some distortion, and the only question is how to have the necessary distortion in such a form as to cause the least practical inconvenience. It is evident that the farther you get from the equator on this Mercator projection, the greater the

distortion, and thus we see that the ten degrees of latitude from the equator to 10° N. Lat. are not much more than half as long as the ten degrees between 50° and 60° N. Lat., at the top of the chart. The scale must, therefore, vary as you go north from the equator, and to measure a given distance on the chart you must refer to that part of the scale at the side of the chart which is in the latitude of the line whose length you wish to measure, the result being given in geographical miles (sixty to a degree of longitude measured on the equator). To illustrate the difference between the appearance of a great circle track on the gnomonic and the Mercator chart, suppose we take the case of a great circle from the Straits of Florida to the north of Ireland. On the gnomonic chart it is evident enough that a straight line, which is here a great circle, from the Straits of Florida to the north of Ireland passes close to Cape Race, the southeastern extremity of Newfoundland. Now, looking at the Mercator chart, it is here clearly evident that a straight line from the Straits of Florida to the north of Ireland passes about ten degrees, or 600 miles, to the southeastward of Cape Race. Therefore, a great circle plotted on the Mercator chart from the Straits of Florida to the north of Ireland would be a curved line starting in a northeasterly direction, approximately parallel to the coast of the United States, and curving close to Cape Race and across the Atlantic to the north of Ireland. When long distances are to be traversed, the great circle route is in general to be preferred on account of its being a shorter distance, especially in the case of steamships, as the weather likely to be encountered is not a matter of such great importance as it is to sailing vessels. To plot the great circle course on a Mercator chart, it is therefore necessary either to work it out by spherical trigonometry, or else to get it practically from the gnomonic chart by drawing the straight line which there represents the great circle track, and then transferring it to the Mercator chart by plotting the positions where the curve crosses certain meridians, and joining the points thus obtained by a curved line.

The variation curves, which I merely mentioned at first, are of great importance to mariners. The compass upon which the sailor has to depend is subject to many errors, the chief of which are *variation* and *deviation:* that is, the magnetic needle rarely points to the true North, but in a direction to the right or left of North,

according to its error at the time and place. The *deviation* of the compass comprises those errors which are *local* in their character; that is, due to the effect of immediately surrounding objects, such as the magnetism of the ship itself—and this is sometimes very great in an iron ship. The *variation* of the compass varies with the position of the ship, as shown by these curves of variation. Thus from Cape Race to New York, the variation of the compass changes from 30° W. to less than 10° W.; and from Cape Race to New Orleans, from 30° W. to more than 5° E., the *agonic* line, or line of *no variation*, being indicated by the heavier double line stretching from the coast near Charleston down through Puerto Rico and the Windward Islands to the northeastern coast of South America. To illustrate these variation curves more clearly, I will present a chart, covering a much wider area than the Pilot Chart, upon which variation curves are plotted for each degree, instead of for each five degrees as on the Pilot Chart. This illustrates very strikingly the positions of the *magnetic* poles of the earth, which do not by any means coincide with the geographic poles. On the contrary, there are two northern magnetic poles and two southern; up north of Hudson's Bay, at the point where these curves converge, there is one magnetic pole, and there is another to the northward of Siberia. Similarly there are two in the Southern Hemisphere, and these four poles of this great magnet, the earth, are constantly but slowly shifting their positions, and just so constantly and surely does the magnetic needle obey these varying but ever present forces, seldom pointing towards the pole which man has marked off on his artificial globe, but always true to the great natural laws to which alone it owes allegiance. The small figures with plus and minus signs, which you see at various places on this chart, indicate the yearly rate of change of variation, and this rate varies at different positions on the chart. Thus, near the Cape Verde Islands, it is plus $\frac{9}{10}$; here the variation increases $\frac{9}{10}$ of a minute a year; farther to the southward, near the South American coast, it is plus $7\frac{4}{10}$, and to the northward, near the Irish Channel, it is minus $7\frac{8}{10}$. Fortunately, however, these changes are small and comparatively regular, and their cumulative effect can be allowed for, when large enough to make it necessary to do so.

I stated at the beginning of my lecture that when near the coast large scale charts are used, giving greater detail, and to

illustrate, I will show you a copy of a chart recently issued by the Hydrographic Office, of Salinas Bay, west coast of Nicaragua. This bay is, I may say, in passing, near the terminus of the projected Nicaragua Canal, and we may yet see the day when it will have become famous. This shows very well the general character of such detailed charts, embracing the hydrography of the coast, and including the topography of the shore a short distance back from the coast line. The figures indicate the depth of water in fathoms at the position where each is plotted, and their meaning is rendered still clearer by the ten-fathom curve, five-fathom curve, and the sanded surface, where the depth is less than three fathoms. This question of *soundings*, and the *depth* of the sea, of vital importance near the coast, is also of great importance out in mid-ocean, far from land. Shoals are often reported at positions where the charts show no dangers to navigation; sometimes these reports are verified, but more often they are mistakes, and the charts were formerly covered with these doubtful dangers, to the never-ending annoyance of navigators. But the apparatus for deep sea sounding has been constantly improved, and our knowledge of the depths of the sea has been increased immensely by the combined efforts of the great maritime nations of the world. These doubtful dangers have thus been constantly reduced in number, and their existence disproved by our better knowledge of the depths of the sea. When a submarine cable is to be laid, the first question is as to the best route to follow, and a chart on which all these soundings are plotted is consulted and the question answered. Let me place before you a chart showing the topography of the bottom of the Atlantic. "The hills of the land stretch not so far as the billows of the sea; the heights of the mountains are not so great as the depths of the ocean."*

To resume consideration of the blue data, or meteorological forecast, let us take a glance at the general change of meteorological conditions during the year, very well illustrated by two charts taken from Berghaus' Physical Atlas, showing the isobars and winds for January and July. The most pronounced feature is

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* The chart referred to was discussed briefly, but it need only be said here that the greatest depth is 4,561 fathoms, a sounding made by Lieutenant-Commander W. H. Brownson, U. S. N., to the northward of Puerto Rico.

the area of high barometric pressure to the southwestward of the Azores, and the permanent area of low pressure near Iceland. There is a greater difference of pressure in winter, the normal high barometer near the Azores being 768 millimetres, and the normal low pressure near Iceland being 747 millimetres, a difference of twenty-one millimetres, or ·85 inches; while in July the normal high barometer is 766 millimetres and the normal low barometer 757 millimetres, a difference of only ·36 inches. To this far greater difference of pressure in winter than in summer is due the greatly increased severity of storms over the North Atlantic during the winter season. The normal barometer over the continent of North America is much higher in January than in July, also, giving rise to the violent westerly and northwesterly gales which surge out over the North Atlantic during the winter season. There are shown, also, on these charts, the limits of the trade winds before spoken of, between which, and just to the northward of the equator, is the region of equatorial rains. The central line of this region has been well named the "Meteorological Equator;" it lies to the northward of the true equator and follows the sun as it changes its declination. "The great 'sun swing' of this calm belt," says Maury, "is annual in its occurrence; it marks the seasons and divides the year into wet and dry for all those places within the arc of its majestic sweep. But there are other subordinate and minor influences which are continually taking place in the atmosphere, and which are also calculated to alter the place of this calm belt, and to produce changes in the thermal status of the air which the trade winds move. These are, unusually severe winters or hot summers; remarkable spells of weather, such as long continued rains or droughts over areas of considerable extent. Either within or near the trade wind belt it is tremblingly alive to all such influences, and they keep it in continual agitation; accordingly we find that such is its state that, within certain boundaries, it is continually changing place and limits. This fact is abundantly proved by the speed of ships, whose log books show that it is by no means a rare occurrence for one vessel, after she has been dallying in the doldrums for days, in the vain effort to cross that calm belt, to see another coming up to her 'hand over fist,' with fair winds, and crossing the belt after a delay in it of only a few hours instead of days." Another authority, Mr. Robert H. Scott,

when speaking of these steady northeast trades, describes how, "when we reach the edge of the trade wind zone, we find the upper currents gradually descending to the sea level. On the peak of Teneriffe (latitude 28° N.), for instance, there are constant southwest winds at the summit. As the autumn comes on the sun moves southwards, the trade winds follow him, and the southwest wind creeps slowly down the mountain side until in winter the whole of the island, from summit to base, is enveloped in this return current, which in summer touches only the highest peak."

Such, then, is a general view of the great climatic changes which take place over the Atlantic as the seasons succeed one another, and the data plotted in blue on the chart indicate these changes graphically to the mariner, in a way to be taken practical advantage of in shaping his course. It was in this field that Maury's genius was so preëminent, and the practical benefits which his studies in marine meteorology have conferred upon commerce must give him as enduring a fame amongst the maritime nations of the world as that of Newton in the realm of science.

You are all more or less familiar, no doubt, with descriptions of the terrific winds and violent seas sometimes encountered by vessels in those terrible storms known as tropical cyclones. West Indian hurricanes, the name by which tropical cyclones in the North Atlantic are generally known, occur most frequently during the summer months, especially in August, and seem to have their origin, as a general rule, about the northern edge of the belt of equatorial rains, near the southern limit of the northeast trades and to the eastward of the Windward Islands. Starting as a whirlwind on a gigantic scale, they at first move bodily westward, sometimes crossing the Gulf of Mexico and reaching the coast of the United States with destructive violence, but more often curving to the northward and then to the northeastward, following up the Gulf Stream towards Newfoundland and circling around the area of permanent high pressure over the mid-Atlantic. Fortunately for sailors, the *direction of rotation* of the wind, which is drawn into and rushes furiously around the area of low barometer in one of these cyclones, is always the same; in the Northern Hemisphere it is invariably in a direction *against the hands of a watch*, as you look at a watch laid down with the face up; in the Southern

Hemisphere it is just the reverse. Upon this well-established fact, together with our knowledge of the progressive motion of the entire storm along a track whose general course is tolerably well known, is based the law of storms, which has been of invaluable assistance to navigators. During the summer months, therefore, special pains are taken to bring before navigators, in the most graphic and condensed form possible, the best rules for action in order to avoid the regions where these storms occur most frequently; or, if actually overtaken by one, in order to manœuvre to the best advantage. The chart which I now show on the screen represents the paths followed by a few West Indian hurricanes, and it will give a good general idea of their character and the general lines along which they move. The name of William C. Redfield, which appears on the title of this chart, is that of an American who is honored by every sailor and every meteorologist as the first thoroughly to grasp and explain the true character of these storms, and whose researches have been of incalculable benefit and have undoubtedly led to the saving of thousands of lives and millions of dollars worth of property at sea during the last half century. Now look at this chart and imagine the terrific winds of one of these tropical cyclones blowing about a centre of very low barometer in a direction indicated by the arrows, and this whole storm system moving along one of these tracks from low to high latitudes; at the centre, mountainous seas, and an almost inconceivable fury of the elements; and you will have a fair general idea of a West Indian hurricane.

During the winter season, although tropical cyclones occasionally occur, the greater portion of the storms which sweep the North Atlantic move along paths which cross the American continent from West to East—the same storms which you see charted on the daily weather map published by the Signal Service—moving over the great lakes, and down the St. Lawrence Valley towards Newfoundland; here they leave the coast, and, gathering renewed energy and violence, proceed on their destructive course towards northern Europe. Following these cyclonic storms come those violent westerly gales which make transatlantic steamship navigation so difficult, especially for westward-bound vessels, as those of you who have crossed the Atlantic at this time of the year can no doubt bear witness. In winter, therefore, it is the province of the

Pilot Chart to graphically forecast and explain *this* feature of ocean meteorology, as indicated by the next diagram, a reprint from the Pilot Chart for last December, with the addition of such material as was considered of great importance, and yet too much to add to the Pilot Chart itself without confusion, for even here we must draw the line somewhere. In this reprint we find discussed the winter storm belt of the North Atlantic and the transatlantic steamship routes recommended for December. Suppose, now, that we should attempt to generalize and summarize on a single chart, by some graphic method, the areas of greatest frequency of existence of barometric minima, or centres of more or less perfectly developed wind systems. Suppose, also, that we should attempt to plot on the same chart the mean paths followed by storms, or, technically speaking, of barometric minima, in order to see at a glance those regions where storms are most frequent, and the general paths which they pursue across the Atlantic. This has already been done for us, with characteristic care and fidelity, by the Deutsche Seewarte, the Hydrographic Office of the German Empire, and this chart I will now project upon the screen. These shaded areas are the regions of greatest frequency of barometric minima. The tracks indicated by heavier or lighter arrows are the paths along which storms travel with greater or less frequency. What a marked predominance to the northward, especially up towards that permanent area of low barometer near Iceland. Only one exception can be taken to this chart: it does not give sufficient prominence to the West Indian hurricane track; there were more of these tropical cyclones during two months last summer than are represented on this chart for an entire year. At the same time, the last hurricane season may be fairly said to have been one of exceptional violence.

Let us here pause for a moment and briefly review the ground that has been covered by my lecture thus far, and then as briefly outline what is yet to come: We have now considered successively the base of the Pilot Chart, the blue data, and the red data, first briefly and in a very general way, and then returning to the base and the blue data in order to enlarge upon each as far as possible, consistently with the limited time at our disposal. We shall next revert in a similar way to the red data, and finally consider briefly the methods by which reports are collected from masters

of vessels, and utilized in the preparation of the Chart; its publication, circulation and practical use; and the present condition and prospects of our commercial marine, to whose interests the work of the Hydrographic Office is so largely devoted.

(*To be continued.*)

MACHINE DESIGNING.

BY JOHN E. SWEET.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *Monday, January 30, 1888.*]

The Lecturer was introduced by the SECRETARY of the INSTITUTE, and spcke as follows:

Ladies and Gentlemen, Members of the INSTITUTE: "Carrying coals to New Castle," the oft-quoted comparison, fittingly indicates the position I place myself in when attempting to address members of this INSTITUTE on the subject of machine designing.

Philadelphia, the birthplace of the great and nearly all the good work in this, the noblest of all industrial arts, needs no help or praise at my hands, but I hope her sons may be prevailed upon to do in their right way what I shall try to do roughly—that is, formulate some rules or establish principles by which we, who are not endowed with genius, may so gauge our work as to avoid doing that which is truly bad. No great author was ever made by studying grammar, rhetoric, language, history, or by imitating some other author, however great. Neither has there ever been any great poet or artist produced by training. But there are many writers who are not great authors, many rhymsters who are not poets, and many painters who are not artists; and while training will not make great men of them, it will help them to avoid doing that which is absolutely bad; and so may it not be with machine designing? If there are among you some who have a genius for it, what I shall have to say will do you no good, for genius needs no rules, no laws, no help, no training, and the sooner you let what I have to say pass from your minds, the better. Rules only hamper the man of genius, but for us, who either from

choice or necessity work away at machine designing without the gift, cannot some simple ruling facts be determined and rules formulated or principles laid down by which we can determine what is really good, and what bad? One of the most important and one of the first things in the construction of a building is the foundation, and the laws which govern its construction can be stated in a breath, and ought to be understood by everyone. Assuming the ground upon which a building is to be built to be of uniform density, *the width* of the foundation should be in proportion to the load, the foundation should taper equally on each side, and the centre of the foundation should be under the centre of pressure. In other words, it is as fatal to success to have too much foundation under the light load as it is too little under a heavy one.

Cannot we analyze causes and effects, cost and requirements, so as to formulate some simple laws similar to the above by which we shall be able to determine what is a good and what a bad arrangement of machinery, foundation, framing or supports? A vast amount of work is expended to make machines true, and the machines, or a large majority of them, are expected to produce true work of some kind in turn. Then, if this be admitted, cannot the following law be established—that every machine should be so designed and constructed that when once made true it will so remain, regardless of wear and all external influences to which it is liable to be subjected. One tool-maker says that is right, and another that it cannot be done. No matter whether it can or cannot, is it not the thing wanted, and if so, is it not an object worth striving for? One tool-maker says that all machine tools, engines and machinery should set on solid stone foundations. Should they? They do not always, for in substantial Philadelphia some machine tools used by machine builders stand upon second floors, or, perhaps, higher up; and of these machine tools none, or few at least, except those mounted upon a single pedestal, are free from detrimental torsion where the floor upon which they rest is distorted by unequal loading. But to first consider those of such magnitude as to render it absolutely necessary to erect them —not rest them—on masonry, is due consideration always taken to arrange an unequal foundation to support the unequal loads?—and they cannot be expected to remain true if not. When one

has the good fortune to have a machine to design of such extent that the masonry becomes the main part of it, what part of the glory does he give to the mason? Is the masonry part of it always satisfactory, and is not this resorting to the mason for a frame rather than a support adopted on smaller machines than is necessary? Is it necessary even in a planing machine of forty feet length of bed and a thirty-foot table? Could not the bed be cast in three pieces—the centre a rectangular box 5, or 6, or 7 feet square, 20 feet long, with internal end flanges, ways planed on its upper surface, and ends squared off—a monster perhaps, but if our civil engineers wanted such a casting for a bridge they'd get it. Add to this central section two bevel pieces of half the length, and set the whole down through the floor where your masonry would have been and rest the whole on two cross walls, and you would have a structure that if once made true would remain so regardless of external influences. Cost? Yes; and so do Frodsham watches—more than "Waterbury." It may be claimed, in fact, I have seen lathes resting on six and eight feet, engines on ten, and a planing machine on a dozen. Do they remain true? Sometimes they do and many times they do not. Is the principle right? Not when it can be avoided; and when it cannot be avoided, the true principle of foundation building should be employed. * * * A strange example of depending on the stone foundation for not simply support, but to resist strain, may be found in the machines used for bevelling the edges of boiler plate. Not so particularly strange that the first one might have, like Topsy, "growed," but strange because each builder copies the original. You will remember it, a complete machine set upon a stone foundation, to straighten and hold a plate, and another complete machine set down by the side of it and bolted to the same stone to plane off the edge; a lot of wasted material and a lot of wasted genius, it always seems to me. Going around Robin Hood's barn is the old comparison. Why not hook the tool carriage on the side of the clamping structure, and thus dispense with one of the frames altogether?

Many of the modern builders of what Chordal calls the Hyphen Corliss Engine claim to have made a great advance by putting a post under the centre of the frame, but whether in acknowledgment that the frame would be likely to go down or the stone-

work come up I could never make out. What I should fear would be that the stone would come up and take the frame with it. Every brick mason knows better than to bed mortar under the centre of a window sill; and this putting a prop under the centre of an engine girder seems a parallel case. They say Mr. Corliss would have done the same thing if he had thought of it. I do not believe it. If Mr. Corliss had found his frames too weak, he would soon have found a way to make them stronger.

John Richards, once a resident of this city, and likely the best designer of wood-working machinery this country, if not the world, ever saw, pointed out in some of his letters the true form for constructing machine framing, and in a way that it had never been forced on my mind before. As dozens, yes hundreds, of new designs have been brought out by machine tool-makers and engine builders since John Richards made a convert of me, without anyone else, so far as I know, having applied the principle in its broadest sense, I hope to present the case to you in a material form, in the hope that it may be more thoroughly appreciated.

The usual form of lathe and planer beds or frames is two side plates and a lot of cross girts; their duty is to guide the carriages or tables in straight lines and carry loads resisting bending and torsional strains. If a designer desires to make his lathe frame stronger than the other fellows, he thinks, if he thinks at all, that he will put in more iron, rather than as he ought to think, how shall I distribute the iron so it will do the most good.

In illustration of this peculiar way of doing things, which is not wholly confined to machine designers, I should like to relate a story, and as I had to carry the large end of the joke, it may do for me to tell it.

While occupying a prominent position, and yet compelled to carry my dinner, my wife thought the common dinner pail, of which you are probably familiar (by sight, of course), was not quite the thing for a professor (even by brevet) to be seen carrying through the streets. So she interviewed the tinsmith to see if he could not get up something a little more tony than the regulation fifty-cent sort. Oh, yes, he could do that very nicely. How much would the best one he could make cost? Well, if she could stand the racket he could make one worth a dollar. She thought

she could, and the pail was ordered, made and delivered with pride. Perhaps you can guess the result. A *fac-simile* of the original, only twice the size.

Now this is a very fair illustration of the fallacy of making things stronger by simply adding iron. To illustrate what I think a much better way, I have had made these crude models (see *Fig. 1*), for the full force of which, as I said before, I am indebted to John Richards; and I would here add that the mechanic who has never learned anything from John Richards is either a very good or very poor one, or has never read what John Richards has written or heard what he has had to say.

Three models as shown in *Fig. 1* were exhibited; all were of the same general dimensions and containing the same amount of material. The one made on the box principle, *c*, proved to be fifty per cent. stiffer in a vertical direction than either *a* or *b*, from twenty to fifty times stiffer sidewise, and thirteen times more rigid against torsion than either of the others.

However strong a frame may be, its own weight and the weight of the work upon it tends to spring it unless evenly distributed, and to twist it unless evenly proportioned. For all small machines the single post obviates all trouble, but for machine tools of from twice to a half dozen times their own length the single post is not available. Four legs are used for machines up to ten feet or so, and above that legs various and then solid masonry. If the four legs were always set upon solid masonry, and levelled perfectly when set, no question could be raised against the usual arrangement, unless it be this: Ought they not to be set nearly one-fourth the way from the end of the bed? or to put it in another form: will not the bed of an iron planing machine twelve feet in length be equally as well supported by four legs if each pair is set three feet from the ends—that is, six feet apart—as by six legs, two pair at the ends and one in the centre, and the pairs six feet apart? There being six feet of unsupported bed in either case, with this advantage in favor of the four over the six, settling of the foundation would not bend the bed.

It is not likely that one-half of the four-legged machine tools used in this country are resting upon stable foundations, nor that there ever will be; and while this is a fact it must also remain a fact that they should be built so as to do their best on an unstable

one. Any one of the thousand iron planing machines of the country, if put in good condition and set upon the ordinary wood floors, may be made to plane work winding in either direction by shifting a moving load of a few hundred pounds on the floor from one corner of the machine to the other, and the ways of the ordinary turning lathe may be more easily distorted still. Machine-tool builders do not believe this, simply because they have not tried it. That is, I suppose this must be so, for the proof is so positive, and the remedy so simple, that it does not seem possible they can know the fact and overlook it. The remedy in the case of the planer is to rest the structure on the two housings at the rear end and on a pair of legs about one-fourth of the way back from the front, pivoted to the bed on a single bolt as near the top as possible.

A similar arrangement applies to the lathe and machine tools of that character—that is, machines of considerable length in proportion to their width, and with beds made sufficiently strong within themselves to resist all bending and torsional strains, fill the requirements so far as all except wear is concerned; that is, if the frames are once made true they will remain so regardless of all external influences that can be reasonably anticipated.

Among wood-working machines there are many that cannot be built on the single rectangular box plan—rested on three points of support. Fortunately the requirements are not such as demand absolute straight and flat work, because, in part from the fact that the material dealt with will not remain straight and flat even if once made so; and in the design of wood-working machinery it is of more importance to so design that one section or element shall remain true within itself, than that the various elements should remain true with one another.

The lathe, the planing machine, the drilling machine, and many other of the now standard machine tools will never be superseded, and will for a long time to come remain subjects of alteration and attempted improvement in every detail. The head-stock of a lathe—the back gear in particular—is about as hard a thing to improve as the link motion of a locomotive. Some arrangement by which a single motion would change from fast to slow, and a substitute for the flanges on the pulleys, which are intended to keep the belt out of the gear, but never do, might be improvements.

If the flanges were cast on the head-stock itself, and stand still, rather than on the pulley, where they keep turning, the belt would keep out from between the gear for a certainty. One motion should fasten a foot-stock, and as secure as it is possible to secure it, and a single motion free it so it could be moved from end to end of the bed. The reason any lathe takes more than a single motion is because of elasticity in the parts, imperfection in the planing, and from another cause infinitely greater than the others, the swinging of the hold-down bolts.

Should not the propelling powers of a lathe slide be as near the point of greatest resistance as possible, as is the case in a Sellers lathe, and the guiding ways as close to the greatest resistance and propelling power as possible, and all other necessary guiding surfaces made to run as free as possible?

A common expression to be found among the description of new lathes is the one that says "the carriage has a long bearing on the ways." Long is a relative word, and the only place I have seen any long slides among the lathes in the market is in the advertisements. But if anyone has the courage to make a long one they will need something beside material to make a success of it. It needs only that the guiding side that should be long, and that must be as rigid as possible—nothing short of casting the apron in the same piece will be strong enough, because with a long, elastic guide heavy work will spring it down and wear it away at the centre, and then with light work it will ride at the ends with a chattering cut as a consequence.

An almost endless and likely profitless discussion has been indulged in as to the proper way to guide a slide-rest, and different opinions exist. It is a question that so far as principle is concerned there ought to be some way to settle which should not only govern the question in regard to the slide-rest of a lathe, but all slides that work against a torsional resistance, as it may be called—that is, a resistance that does not directly oppose the propelling power; in other words, in a lathe the cutting point of the tool is not in line with the lead screw or rack, and a twisting strain has to be resisted by the slides, whereas, in an upright drill the sliding sleeve is directly over and in line with the drill, and subject to no side strain.

Does not the foregoing statement "that the propelling power should be as near the resistance as possible, and the guide be as near in line with the two as possible," embody the true principle? Neither of the two methods in common use meet this requirement to its fullest extent. The two-V New England plan seems like sending two men to do what one can do much better alone; and the inconsistency of guiding by the back edge of a flat bed is prominently shown by considering what the result would be if carried to an extreme. If a slide such as is used on a twenty-inch lathe were placed upon a bed or shears twenty feet wide, it would work badly, and that which is bad, when carried to an extreme, cannot well be less than half bad when carried half way.

The ease with which a cast-iron bar can be sprung is many times overlooked. There is another peculiarity about cast iron, and likely other metals, which an exaggerated example renders more apparent than can be done by direct statement. Cast iron, when subject to a bending strain, acts like a stiff spring, but when subject to compression it dents like a plastic substance. What I mean is this: if some plastic substance, say a thick coating of mud in the street, be levelled off true, and a board be laid upon it, it will fit, but if two heavy weights be placed on the ends, the centre will be thrown up in the air far away from the mud; so, too, will the same thing occur if a perfectly straight bar of cast iron be placed on a perfectly straight planer bed—the two will fit, but when the ends of the bar are bolted down the centre of the bar will be up to a surprising degree. And so with sliding surfaces when working on oil. If, to any extent elastic, they will, when unequally loaded, settle through the oil where the load exists and spring away where it is not.

The tool-post, or tool-holder that permits of a tool being raised or lowered and turned around after the tool is set, without any sacrifice of absolute stability, will be better than one in which either one of these features is sacrificed. Handiness becomes the more desirable as the machines are smaller, but handiness is not to be despised even in a large machine, except where solidity is sacrificed to obtain it.

The weak point in nearly all (and so nearly all that I feel pretty safe in saying all) small planing machines is their absolute weakness as regards their ability to resist torsional strain in the bed,

and both torsional and bending strain in the table. Is it an uncommon thing to see the ways of a planer that has run any length of time cut? in fact, is it not a pretty difficult thing to find one that is not cut, and is this because they are overloaded? Not at all. Figure up at even fifty pounds to the square inch of wearing surface what any planer ought to carry, and you will find that it is not from overloading. Twist the bed upon the floor (and any of them will twist as easy as two bass-wood boards) and your table will rest the hardest on two corners. Strap, or bolt, or wedge a casting upon the table, or tighten up a piece between a pair of centres eight or ten inches above the table, and bend the table to an extent only equal to the thickness of the film of oil between the surface of the ways, and the large wearing surface is reduced to two wearing points. In designing it should always be kept in mind, or, in fact, it is found many times to be the correct thing to do to consider the piece as a stiff spring, and the stiffer the better. The tooth of a gear wheel is a cast-iron spring, and if only treated as would be a spring many less would be broken. A point in evidence:

The pinions in a train of rolls, which compel the two or more rolls to travel in unison, are necessarily about as small at the pitch line as the rolls themselves; they are subject to considerable strain and a terrible hammering by back-lash, and break discouragingly frequent, or do when made of cast iron, if not of very coarse pitch, that is, with very few teeth—eleven or twelve sometimes.

In a certain case it became desirable to increase the number of teeth, when it was found that the breakages occurred about as the square root of their number, when the form was changed by cutting out at the root in this form (*Fig. 2*) the breakage ceased.

a, *Fig. 2*, shows an ordinary gear tooth and *b*, the form as changed; *c* and *d* show the two forms of the same width, but increased to six times the length. If the two are considered as springs, it will be seen that *d* is much less likely to be broken by a blow or strain.

The remedy for the flimsy bed is the box section; the remedy for the flimsy planer table is the deep box section, and with this advantage, that the upper edge can be made to shelve over above the reversing dogs to the full width between the housings.

The parabolic form of housing is elegant in appearance, but

theoretically right only when of uniform cross section. In some of the counterfeit sort the designers seem to have seen the original Sellers, remembering the form just well enough to have got the curve wrong end up, and knowing nothing of the principle have succeeded in building a housing that is absolutely weak and absolutely ugly, with just enough of the original left to show from where it was stolen. If the housing is constructed on the brace plan, should not the braces be straight, as in the old Bement, and the centre line of strain pass through the centre line of the brace. If the housing is to take the form of a curve, the section should be practically uniform, and the curve drawn by an artist. Many times housings are quite rigid enough in the direction of the travel of the table, but weak against side pressure. The hollow box section, with secure attachment to the bed and a deep cross beam at the top, are the remedies

Raising and lowering cross heads, large and small, by two screws is a slow and laborious job, and slow when done by power. Counter-weights just balancing the cross head, with metal straps rather than chains or ropes, large wheels with small anti-friction journals, and the cross head guarded by one post only, changes a slow to a quick arrangement, and a task to a comfort. Housings of the hollow box section furnish an excellent place for the counter-weights.

The moving head, which is not expected to move while under pressure, seems to have settled into one form, and when hooked over a square ledge at the top, a pretty satisfactory form, too. But in other machines built in the form of planing machines, in which the head is traversed while cutting, as is the case with the profiling machine, the planer-head form is not right, both the propelling screw or whatever gives the side motion, should be as low down as possible, as should also be the guide.

There is a principle underlying the Sellers method of driving a planer table that may be utilized in many ways. The endurance goes far beyond any man's original expectations, and the explanation, very likely, lays in the fact that the point of contact is always changing. To apply the same principle to a common worm gear it is only necessary to use a worm in a plain spur gear, with the teeth cut at an angle the wrong way, and set the worm shaft at an angle double the amount rather than at 90°. Such a worm gear

will, I fancy, outwear a dozen of the scientific sort. It would likely be found a convenience to have the head of a planing machine traverse by a handle or crank attached to itself, so it could be operated like the slide rest of a lathe, rather than as is now the case from the end of the cross head. The principle should be to have things convenient, even at an additional cost. Anything more than a single motion to lock the cross head to the housing or stanchions, should not be countenanced in small planers at least. Many of the inferior machines show marked improvements over the better sorts, so far as handiness goes, while there is nothing to hinder the handy from being good and the good handy.

When we consider that since the post-drilling machine first made its appearance, there have been added Blasdell's quick return, the automatic feed, belt-driven spindles, back gears placed where they ought to be, with many minor improvements, it is not safe to assume that the end has been reached; and when we consider that as a piece of machine designing, considered in an artistic sense entirely, the Bement post drill is the finest the world ever saw (the Porter-Allen engine not excepted, which is saying a good deal), is it not strange that of all mechanical designs none other has taken on such outrageous forms as this.

One thing that would seem to be desirable, and that ordinary skill might devise, is some sort of snap clutch by which the main spindle could be stopped instantly by touching a trigger with the foot; many drills and accidents would be saved thereby. Of the many special devices I have seen for use on a drilling machine, one used by Mr. Lipe might be made of universal use. It is in the form of a bracket or knee adjustably attached to the post, which has in its upper surface a V into which round pieces of almost any size can be fastened, so that the drill will pass through it diametrically. It is not only useful in making holes through round bars, but straight through bosses and collars as well.

The radial drill has got so it points its nose in all directions but skyward, but whether in its best form is not certain. The handle of the belt shipper, in none that I have seen, follows around within reach of the drill as conveniently as one would like.

As the one suggestion I have to make in regard to the shaping machine best illustrates the subject of maintaining true wearing surfaces, I will leave it until I reach that part of my paper.

Perfect as are the modern boring machines, both horizontal and vertical (and the reason they average so good is probably because the imitators find no poor ones to copy), there is one thing that might in many cases be found valuable, and that is a rotary spindle driven at various speeds and fixed in a head movable along the cross beam of the vertical machine. This would be complete for boring the crank-pin hole in engine cranks, and a complete plain radial drilling machine, useful in all shops where the machine only has legitimate work enough to keep it employed for a part of the time. Such a machine could hardly be called a compound, and certainly not a combined machine, although used for turning, boring and drilling. Combined tools and machines are seldom successful. A common hammer, which may be said to have two business ends, a lathing hatchet, and Disston's nigger saw, as I believe we used to call it down South, cover nearly the whole ground in tools, and Scott Russell's idea, as expressed in his remark, after viewing a combined machine at the Paris Exposition, may be remembered to advantage. The machine referred to consisted of a central post with a drilling machine on one side and a slotting machine on the other. After staring at it with evident curiosity, the attendant somewhat elated at the apparent interest of his distinguished visitor, asked what he thought of it, to which he replied: "I was thinking if I had that machine which part I would cut off, the drill or the slotter?" What I know about a slotting machine is fairly comparable to Burton's knowledge of the French language. He said he knew the French language by sight, and that's about the extent of my knowledge of a slotter, and possibly this is the reason I could never persuade myself into the belief that they look well or as well as it is possible to make them. The slotting machine, like others of the overhanging class, that is drilling and punching machines, is subject to strains that they have to resist to a disadvantage, and where springing to a certain extent cannot be avoided. Might it not be set down as a principle that the framing should be devised so as to have the springing do the least possible harm. A slotting machine might be so designed that all the spring there was in the machine would have a direct tendency to throw the cut out of square with the table; whereas, if the sliding bar was worked with a walking-beam there would be no detrimental spring whatever. Evil resulting

in a punching machine from springing is of another character altogether; much springing adds immensely to the power required to do the punching, and unless specially designed to avoid such a result, the springing throws the punch out of adjustment with the die, and bad work and dull tools are the result.

If the upper and lower parts of a punching machine are just equally rigid or equally elastic, and the punch and die central between the two, then the springing, however much, would not throw the tools out of register, and would do no harm except the waste of power. The loss of power in springing a machine is sometimes returned when the spring returns, but in a punching machine all power expended in springing the frame is a dead loss. The springing of machine framing, the springing of tools, and the springing, all add to the cost of doing work, not only on account of a loss of power, but in the dulling of the cutters, and in this none more so than the milling machine. The tools or cutters themselves are costly, and the act of cutting, as performed by an ordinary slabbing cutter, differs from nearly all other cutting action. Each separate chip removed is a wedge-shape piece, and the cutting edge of the cutter starts in at the point of the wedge. The appearance of a milled surface, as ordinarily left on soft metal, is unusually more uneven than any feed or imperfection in the cutter accounts for, and it is safe to assume that the teeth of the cutters slip over more or less and then bite and gouge in deeper than if each one took its allotted amount. Both actions tend to dull the cutters, and not only the spring of the machine and cutters tend to produce this result, but an elastic feed motion also contributes to this same result, so that a rigid feed is likely more essential in a milling machine than in any other.

Many have thought that as a remedy for the difficulties arising from the cause above described, that it would be an improvement to feed the work to the milling machine in the opposite direction, that is, so the cutting edges of the milling cutter would start in at the large end of the wedge; but whether this would be an advantage (except, perhaps, in cutting shapes) is doubtful. In the roughing cut the cutting edge would be starting in on the scale, and in finishing flat work the cut is so slight that there could be but little gain.

Milling machines were for years thought to be well adapted for

small work, but not for large, and this idea is likely entertained by many yet, while others believe that the reason it has not proven successful in large work was because there were no large machines, while the truth probably is that the kind of work has more to do with the question of adaptability than the size, and that certain classes of work of whatever size can best be done by rotary cutters, while other kinds will always be best done by the planing, shaping and slotting machines.

What cutting action shall be adopted to perform a certain operation is as much a question in machine designing as any other. The most perfect of all machine work is done by an emery or corundum wheel, and the next of all I have seen is done with what is usually understood, though perhaps not properly, an end mill. Cutting tools, traversing in curved paths across a flat surface, have an advantage in never following over twice in exactly the same path, as is the case in a planer tool, which probably accounts for the absence of chatter; but, on the other hand, the cutting blade traverses over eleven inches of distance to finish a seven-inch cut. The planer wastes time in stopping, running back and starting, while the traversing blades are always at it.

After a half century of study over the lathe and planer, improvement still goes on, and in this view what may we not expect a quarter of a century hence of the milling and traversing cutters and emery-cutting devices?

In all our planning and all our study there is one vital principle that is hardly ever thought of and never mentioned. We all look for the best new machine, but who to see which is to be the best old one? The mathematicians tell us which is the most perfect gear, but all their calculations are based on a new one, and no thought given to the one-half or three-fourths worn out. An engine cylinder needs no counter-bore when new, but experience has shown the necessity for it when old; and short cross heads, working on long slides without overlapping at the ends, soon wear the slides concave and themselves rounding, with the result, two curved surfaces of unequal radius always growing worse. The slides I will speak of later on. The gear tooth needs an undercut at the root as much as the cylinder needs a counter-bore. The epicycloidal may be the best form for a new gear, and the single arc odontograph for an old one.

With the exception of the J. Morton Poole grinding machine, nearly every machine tool depends for the accuracy of its work upon the accuracy of sliding surfaces. In the best work special methods are adopted to make them true, after which they are left to fate to keep them so. Who has ever deliberately undertaken to plan and build a planing machine that should maintain perfect truth during its entire existence? The planing machine has a short table working on a long bed, the milling machine a long table working on a short bed—the lathe a short rest on long slides, and the shaper a long slide in a short guide.

The tool builder would laugh at the engine builder who should run a cross head on guides not cut away so the cross head would overrun at the ends; and yet he makes the sliding block on the cross feed of his lathe six inches long working on a dovetail two feet long, sometimes running off at one end and never at the other. The sum of the two fitted surfaces is thirty inches. If divided equally, that is, a fifteen-inch sliding on a fifteen-inch dovetail, the two would remain true and be a good job as long as the lathe lasted. This is one of the places where for lathes of moderate size there is no excuse for anything but wearing surfaces of equal length. The designer who finds any difficulties in this that he cannot overcome, has too little genius for the job. Equal length sliding surfaces can usually be employed in all the slides on milling machines, punching machines and many others, and wherever possible the use of any other arrangement is simply poor designing, to give it the mildest criticism possible. A short sliding block on a long guide invariably gets bad sooner or later, and refitting becomes necessary.

The sliding-head of a shaper invariably made longer than its guide, is an ever-present nuisance and one that can be abated. The requirements call for a slide to work at all sorts of stroke from an inch to a foot and at positions varying as much as a foot. As now made, much of the back end of the sliding arm does not get a 100th part of the wear that the front end does, and often none at all. As a result in many establishments the thing may be worked for a year at short stroke and in one place; then when the attempt is made to use it in a different position, it is so loose in one position and so tight in another as to be worse than useless. The remedy is easy. Make the two sliding surfaces of a length

and attach the connecting rod to an immovable pin, then both ends of the slide will always overrun, whether the stroke is an inch or a foot. To provide for the varying position of cut, the plan shown in *Fig. 3*, is presented.

This slide is guided in the usual way and driven by a connecting rod rigidly attached to the side or bottom, as most convenient. Instead of the slides carrying a head and tool post, it is bored out, split and provided with two binding bolts, so as to grasp the tubular arm, which, when loose, may be slid or turned in any position, and then firmly bound in that position.

The diameter of the hollow projecting arm need not be much larger than the width of the tool holder—five or six inches—in an ordinary ten-inch or twelve-inch machine. The sliding arm being provided with a featherway and surrounded by a graduated worm-gear or ring feathered to it, the bar may be rotated to any angle and adjusted endwise without disturbing or losing the angle at which it is set. A second advantage of this arrangement would be the removal of the ordinary side projections which so frequently come in the way when using the present machines.

I have not presented this so much to represent an improvement in shapers, as to show how it is possible in machines of this class to use slides of equal length, maintain their proper position and get adjustment of tool. But you will say it is not so simple. True. Neither is a watch as simple as an hour-glass, nor a Corliss engine as simple as a Hero. Good things cost more than poor. All improvements have to be paid for. Sliding surfaces, such as those of the planing machine and slide rest of a lathe, cannot be of equal length ; then the question arises, are they made to maintain their truth as well as possible ?

The table or platen of a planing machine cannot be used successfully for its entire length unless the bed upon which it runs is longer than itself—usually about one-half longer—and when so arranged and used to any considerable extent on short work it wears the bed concave and itself convex to fit. This would occur even were both absolutely rigid, but is much aggravated by an elastic table, which may be sprung one way or another every time a new piece is secured to it. A rigid table with wearing surfaces so generous as to always float on the oil, however heavy the load, would keep true a long time, or if the wearing surfaces were cut away

towards the end of the bed, as shown by this model (see *Fig. 4*), the result would be practically perfect. If the slide rest of a lathe be long enough, strong enough, has wearing surface enough of the right sort, and any man has courage enough to cut away the ways on the plan just shown, one would remain true for a time far beyond anything yet produced. And so with all slides; in fact the principle can be applied to all wearing surfaces where from necessity a short piece must work on a long guide, or a short nut on a long screw.

Journals with end play should have bearings and box of the same length; collars, or the bosses, on wheels that resist end thrust on shafts, should rest upon or run against bosses of exactly their own diameter. The guides or slides of steam engines are as often too long as the cross heads are too short, for one is as fatal to enduring truth as the other.

I have used the best-known tools to illustrate principles that are employed in all machines; the assembling or combining the sliding, the rotary, angular and screw motions, is invention or design in proportion to the extent of originality. The construction of the framing calls for the exercise of many faculties; it must be suitable, strong enough, rigid enough (entirely a different quality), of such form that the patterns can be readily made, if to be of cast metal, so as to be easily forged, if of forging, so it can be machined; and last, but not least, so it will look right—in fact, lacking nothing but the poetry to be artistic. This looks, this artistic, this good or bad, this one thing that is past reason, this thing that we can't argue about, but feel, is that part that much more can be thought about than said; that part which we may never be able to tell what to do to be right, and at most, but few things that may be depended upon as positively wrong.

Whatever nature does she does right; whatever the designer does different from what nature would do if she had the same work in hand, cannot be right. Nature at her best, roots her trees to the ground, tapers their trunks, and stretches out their far-reaching branches, but the branches all combined would not exceed the trunk in size; and the branches all grow out from the trunk on one and the same plan—never two or three growing up and then one down, as we find them in some late drilling machines, but all follow the same grand plan. If there is ever an exception to this

in nature it is by distortion, a deformity, an abortion. There has not yet been so many good machines designed to call for an abortion for the sake of variety, for, in fact, there has been so many abortions that the good ones make the variety.

The causes that have been instrumental in producing such a large percentage of poor designs, were these: our early draftsmen were architectural draftsmen; and when the aspiring mechanic required a drawing for his new machine he employed the architect, who brought with him his ornaments and forgot the principles. His posts were columns without cornice or pediment, and when his frame, which he did not understand, did not look right, he attempted to ornament it into shape. This state of affairs was made worse by another set of draftsmen who neither understood architecture nor mechanics, and lacked genius. Machines made from such designs have been scattered throughout the country, imitated and counterfeited, with their worst features made most prominent; cuts published in all the technical journals without a comment as to their merits or demerits in design; and now, to add to this, our colleges are going on from bad to worse by placing before their students models of motions and machines, constructed as machines never are constructed, or would not work if they were, and placing the students under a professor of drawing who teaches them how to make drawings rather than how to represent a properly designed machine, or teach them to know what constitutes good and bad designing.

The columns of all the best buildings in the world are straight—that is, their axial line. When their own weight is a considerable fraction of the whole weight, they have a considerable taper; when their own weight is but a small fraction, there is only taper enough to make them appear straight. I do not believe a computation was ever made to determine that this was right, but the designers were led to it by their own instinct. When the sides of a tapering column are perfectly straight, they will appear concave. This fact, known to the architects in Balbec days, was remedied by making the lines curved just enough so the columns looked straight. Their imitators, discovering the fact without being able to appreciate it, did as imitators usually do, magnified their discovery and mutilated a design they could not appreciate.

Take the columns of the different orders and styles of architecture—Doric, Tuscan, Ionic, Corinthian, Norman and Gothic. No man at the present day will attempt to add to or take from in the hope of betterment, and yet the axis of every one is a straight line. No one of sense will ever attempt to improve them by making them crooked, because the straight line is right; and so with all the successful single-post machine designs—they are straight. It is true that George Richards, of Manchester, gives the sides of the post a noble sweep, but the axial line of the post remains straight.

It is true the supports of a machine are subject to oblique as well as vertical strains, while the columns of a building are not; but why do we fancy that a crooked member will resist those strains better than a straight one? The reverse curve is a line of beauty—yes, in an ornament, but in a thing, not, unless there is a constructive demand for such a curve. The outline of a Porter-Allen engine bed is a reverse curve. True; and it's also true there was no room for a straight one. The noblest architecture is grand because it is consistent. Our machine designs are noble in proportion to their consistency. Every feature of every noble style of architecture is conceived in the same spirit. Every feature of a Grecian building, its columns, its openings, its mouldings, itself, were in one style, and so of the Roman, the Gothic and the Norman, and every feature of a machine design should possess the same general characteristic. The Grecian and Roman columns were round, and for the service they had to perform round was the best possible form they could be. The Gothic columns are not round usually, because for carrying the arched ribs of the vaulted ceilings, clustered columns conform to the arches and best serve the purpose. In machinery, a square or rectangular form is best, because, usually, there are things to be added, and brackets or slides are most easily attached to a flat surface. The shape is consistent, and will never be improved upon. It is one of the things no Queen Ann fashion can overthrow. Fashion follows in machinery as well as in other things, and when it follows because it is the fashion, it is more likely to follow the bad than the good. All our older mechanics can remember when the posts of an iron planing machine were formed to fit various ogee curves—that so-called line of beauty. Does that form look well to anyone to-day?

It has given way to the bold sweep of a single curve, which has come to stay, not simply because it looks better, but when rightly drawn it is right and looks right.

The true form is not a perfect parabola, however, because the case is not one parallel to the fixed beam loaded at one end. The planer post never gets its strain at the extreme end. We cannot trust to the mass of our mechanics to produce tasty designs, because the spirit of our people is not artistic.

The old form of framing and that used yet by the builders of cheap machinery, is H or U section—a style supposed to be strong because the mathematicians say an H section is a strong one, but it is no stronger in any direction than the box and infinitely weaker when subject to torsion. The patterns are costly to make and easily broken in the foundry; there are no cores to make but lots of mending up to do. Your city is not only blessed with good designers, but with good pattern makers and founders besides. I think if a Philadelphia designer should go elsewhere the first man he would send home for would be his old pattern maker and the next the boss foundryman. One who has never tried it can hardly realize how little is the difference between a graceful curve and an ugly one. The man who fails to discover this difference is the one who just fails, whether as a designer or pattern maker.

If an Englishman were set to improve the German design he would put in more iron; if the Frenchman, he would make the form more graceful; if the native Yankee, he would paint it green and stripe it with red; and to change this spirit, the example set by Philadelphia has done more than any other one thing, and it has not been so much by substituting steel-colored paint for green as the substitution of consistent things and forms for inconsistent ones, and doing the thing that was to be done in the simple, right way. This consistency comes, I believe, more from inherent common sense than education, and doing the thing right is more the result of good judgment than mathematical calculation.

It may not be possible to separate in our minds very completely machine designing from mechanical engineering, but in the sense I am endeavoring to devise rules for the one, I feel sure our colleges are entirely overestimating the importance of the higher

mathematics. When one has to use his judgment whether to give a factor of safety of four or ten, his judgment will tell him about how large to make the thing any way; and in another sense, where what Oberlin Smith calls the "anvil principle" becomes an element, the figures are entirely misleading. Or, take the case of the fly-wheel of an engine. It is impossible to begin to figure at all until you have guessed upon the first factor—that is, what per cent. of variation in speed will you accept? For absolutely uniform speed is an impossibility in an ordinary engine, and the extent of variation admissible is entirely guesswork. If you guess twice too much your wheel will be four times too small, and so you will be twice as likely to get it what you want if you guess at the wheel and leave out the figures entirely. It is true that here and there mathematics are useful. In certain cases the higher mathematics are necessary, but usually arithmetic covers the ground, or a few marks on the drawing board, and the slide rule, is a much quicker way. When a class of forty students spend a good part of four years in learning the higher mathematics, with the certainty that at least thirty-eight of them will never have any use for them, and that the other two will forget a large part before the time for them to put them to use arrives, is it not worth questioning the real value of so much application. "Discipline the mind" may be all very well when the mind is the thing that is to do the work, but where something is to be made the mind should never, in the sketch, the drawing or in the mathematics, lose sight of the *thing*, to worship the methods.

For the designing of buildings, the designers, architects, receive special training; for the designing of machines, with some stingy exceptions at our colleges, no training is had, and every man does it himself.

If anyone is to build a house he employs an architect to make a plan; if we are to build a machine, none of us think of employing a machine designer. I have known one exception to this. A manufacturer bought a patented invention, with nothing to show what the machine was to be but a wood model—crude in every element. He employed a man to get up some drawings of it, and with the instructions to "put it in shape." For the drawings and the putting it in shape he paid $25, and the result has been quite a fair fortune. If manufacturers would employ designers

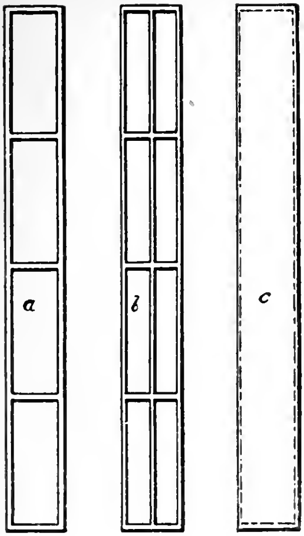

Fig. 1.

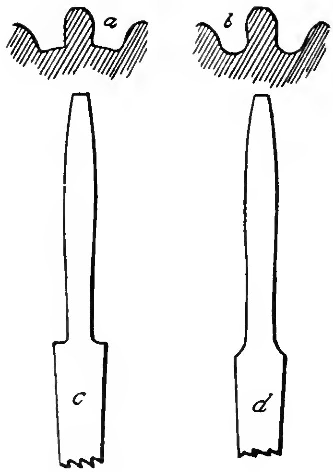

Fig. 2.

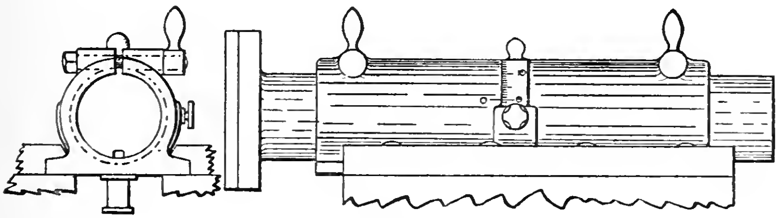

Fig. 3.

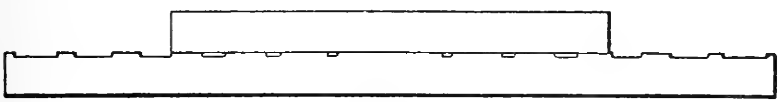

Fig. 4.

a, *b*, *c*, *Fig. 1*, illustrate the models shown by Mr. Sweet, which represented three forms of lathe and planer construction. The box form *c*, proved to be fifty per cent. stronger in its vertical direction than either *a* or *b*, fifty times stronger sidewise than *a* and twenty times stronger than *b* and more than thirteen times stronger than either when subject to torsional strain.

a, *Fig. 2*, represents an ordinary pinion tooth and *b* shows one of the same size strengthened by cutting out metal at the root; *c* and *d* were models showing the same width of teeth extended to six times the length, showing what would be their character if considered as springs.

Fig. 3 shows the suggestion in regard to shaper slide, and *Fig. 4* the method of cutting away the ways of a planer so as to reduce the wearing surface of the bed to the same extent as the table. In small machines the suggestion was made to cut out the spaces by milling, and in large surfaces, such as a planing-machine bed, cast out the spaces and fill them with soft metal.

when they have machines to design as they would architects—I mean real designers, not simply draughtsmen—I believe they would find it an equally profitable investment. This would in many cases cost considerable, because competent designers are scarce, and the reason they are scarce is because, aside from the special gift, the necessary requirements are so varied.

Besides being every inch a mechanic, saturated with the courage to do things new, and right, one needs the genius of an inventor, the training of an engineer, a knowledge of architecture, the experience of a manufacturer, the skill of a master mechanic, the handicraft of many tradesmen, and the spirit of an artist.

On SOME EARLY FORMS of ELECTRIC FURNACES.

No. 4. JOHNSON'S ELECTRIC FURNACE.

By Prof. Edwin J. Houston.

The idea of directly utilizing the intense heat of the voltaic arc for the fusion of refractory substances, for metallurgical or other purposes, suggested itself at quite an early date to the minds of many inventors.

That such should have been the case is quite intelligible. When the earlier experimenters with the voltaic arc saw the most refractory substances melt readily in its very great heat, it is natural that they should think of applying it to such operations as required high temperature in a limited space.

In some of the early forms of electric furnaces to which we have already referred, the heat of the arc was indirectly utilized.

That which we shall now describe employed this heat directly for the smelting of ores.

On the 22d of March, 1853, John Henry Johnson, filed in the office of the Commissioner of Patents of Great Britain a provisional specification for Letters-Patent for an invention entitled "Smelting Iron and Other Ores." This application was numbered 700 of 1853. The completed specification for the same was never filed.

Johnson describes a furnace in which metallic ores, particularly iron, are smelted in a furnace the heat of which is of electric origin. The ore to be treated, previously ground, was mixed with charcoal

and dropped between the poles of large electrodes across which a voltaic arc was established. The ore thus treated was separated into molten metal and slag by being received in a suitable vessel placed above the electric furnace proper, in which it was maintained in a fused state by any suitable heat. In this vessel the molten mass separated in layers of different densities, in the well-known manner.

The inventor gives the following description of his form of furnace in the provisional specification before referred to.

"This invention consists in the smelting of metallic ores, particularly iron ore, which have been previously mixed with charcoal, by the application of the electric light to that purpose. This is effected by dropping the ore or metal to be melted between the poles of two large electrodes, which are connected in the ordinary manner with a galvanic battery. The electric light thus produced smelts the ore as it passes through it, and the melted metal with the slag falls into a receiver below, where it is kept in a state of fusion by a suitable furnace placed beneath it, the different specific gravities of the 'slag' and melted metal keeping them separate in the receiver."

The specification also describes a modified form of furnace in which the ore to be treated is automatically fed into and through the electric furnace proper. In this form, as will be seen, one of the electrodes is made hollow and contains the mixture of ore and charcoal. Provision is also made for the advance of the electrodes on their consumption in the arc.

This modification is described as follows:

"By another arrangement the two electrodes are placed at a slight angle, and the higher one of the two is made hollow and filled with the ore to be reduced. This ore is gradually pushed forward, as it melts, by a piston and screw rod revolving within the hollow of the electrode. When the whole has been reduced, the piston is withdrawn and the electrode filled again. As the electrodes are consumed, they are caused to advance by screw spindles working into fixed nuts, and attached to armatures or sockets on the end of the electrodes, as by the apparatus a continuous supply of electrodes may be attained in various other ways."

Johnson's electric furnace, differed from any as yet described in the fact that, although the heat employed for the direct fusion

and treatment of the ores was purely electric in its origin, there was combined therewith a second furnace in which the fused material collected and separated into molten metal and slag. That is to say, this early form of furnace consisted of the following elements in combination, viz:

(1) An electric furnace proper, the function of which was to directly fuse and treat the ore or other material by the direct application of the heat of the voltaic arc.

(2) Of a subsidiary or secondary furnace the function of which was to receive the melted and treated materials, and maintain them at the temperature of fusion until a complete separation was effected of the slag and the molten metal as a joint result of the action of such heat, and of their differences of density.

The combination of these two elements in an electric furnace, was, considering the date of the invention, exceedingly ingenious. We see no reason why a furnace constructed on the lines here pointed out should not be practical for the smelting or reduction of certain ores.

It is but proper to remark that the name Johnson appended to the provisional specification, may be that of the agent to whom the same was intrusted and not that of the inventor. No mention, however, is made in the specification, as is usually done, of the same being a communication, and it is possible that Mr. Johnson was the inventor. The disadvantages of thus taking out the invention in the name of the attorney, in place of that of the inventor are manifest, and require no further comment.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, *January 14, 1888.*

No. 5. WATSON AND PROSSER'S ELECTRIC FURNACES.

In the early forms of electric furnaces thus far described, the electric heat has been the sole, or at least the principal source of heat employed. In the forms of furnaces described by J. W. Watson and W. Prosser of England in 1853, the electrical heat formed but an inconsiderable part of the heat employed.

The Watson and Prosser furnaces are described in Brit. Pat. No. 5 of 1853, for "An improved method of manufacturing steel and of carburizing iron."

The electric current is employed for the manufacture of steel in three different ways, viz.:

(1) A mass of molten cast iron is obtained in a suitable furnace or cupola by any of the usual methods. Carbonaceous matter is then added in excess to the metal which combines with it. Two carbon poles, formed of pieces of graphite or gas-retort carbon, are then introduced into the mass, and so connected with a powerful battery as to cause its current to pass through the fused metal. Quoting from the specification of this patent.

"We do not begin to pass the current until the cast iron has been in contact with the carbonaceous matter about two hours. The action of the current is to drive off a portion of the carbon combined with the cast iron, and to reduce the hyper-carburet of iron to a carburet of iron containing 1·5 to 1 per cent. of carbon, or, in other words, to a steel of the composition and properties of shear steel, which has been equalized in its texture and composition by repeated tiltings."

The process just described was also useful, it was claimed, in removing the sulphur or phosphorus with which the metal is so frequently contaminated, and whose presence is so injurious to the steel formed therefrom.

(2) The converting trough in which the bars of iron are submitted to the process of cementation was insulated, and an electric current passed through the bars of iron while packed in the charcoal or other form of carbon. This is described in the specifications as follows:

"We insulate by means of non-conducting substances, such as fire-clay and fire lumps, the ordinary converting trough for making bar iron into steel, and then pass an electric current through the whole number of bars in contact with the carbon or charcoal by uniting their separate ends by stout copper wire of not less than half an inch in diameter clamped on to the ends of the bars, which should be permitted to project through the end stones of the cementing troughs about six inches. By passing an electric current thus through the bars the operation of steeling is much hastened, since bars which by the ordinary process of cementation require from six to eight days to be made into shear steel, may by the passage of the current be steeled in four or five days."

A curious advantage, in addition to the decrease in the time

required is claimed for the electrical cementation of iron. Steel thus formed is, it is claimed, much more uniform in its texture. The steelification is so equalized throughout the mass that the formation of the blisters so common in cemented bars, from the escape of gaseous products, is entirely avoided.

(3) Another process for the formation of steel from iron consists in connecting the mass to be steelified with an electric source by means of poles of graphite or platinum. This is described in the specifications as follows, viz.:

"We carburize iron by making the carbonaceous matter in connection with the metal a conductor of electricity by placing poles, either of graphite or platina, into the cementing substance, such as charcoal, the current then passes equally through the mass. By adopting this mode of carburizing, a steel of moderate hardness is produced in about two days from the commencement of the cementing process. This steel is highly useful for the manufacture of saws and springs."

The broad idea of using electric currents in substantially some of the ways here indicated for the purposes of improving cast iron, or for converting iron into steel, appears to have repeatedly suggested itself to metallurgists, as a few references will show.

Arthur Wall, in British Patent No. 9,946 of 1843, for "Certain Improvements in the Manufacture of Iron," proposes to subject the iron while in the molten state and while congealing to a current of electricity. He also proposes applying electricity to "iron in a smelting furnace or cupola" by inserting one battery terminal at the top hole, and the other at one of the tuyre holes. He suggests the application of electric currents to "the iron in the puddling or balling furnace." This is effected by connecting one battery terminal with part of the fused metal and the other stirring or balling rod.

F. H. Holmes, in describing, in Brit. Pat. No. 573 of 1856, the magnetic-electric machine so well and favorably known in England some time ago, in connection with the name of the inventor, claims the use of the current produced by this machine, as follows:

"In the manufacture of iron and steel for the purposes of obtaining a better product and in less than the ordinary time" and for "The separation of metals from their ores in any of the ways already proposed for applying the agency of electric currents."

W. H. Dawes, in British Patent No. 1,087 of 1867, for "The manufacture of iron," proposes to pass an electric current through molten iron.

E. C. Monckton, in British Patent No. 1,890 of 1869, for the "Manufacture of iron and steel," proposes "To produce iron direct from the smelting furnace in its greatest purity" by the use of electric currents passed through the molten metal.

Chas. Motier Nes, in British Patent No. 866 of 1871, for the "Manufacture of iron and steel, and re-working of old iron and steel," describes the use of electricity in connection with the various processes mentioned.

Forquignon and Ehrmann, in British Patent No. 2,712 of 1872, for the "Purification of cast iron, malleable iron, cast steel, and malleable steel, etc," proposes to employ currents from magneto-electric machines to improve the quality of molten metals.

The fact that none of the processes here described for the utilization of electric currents appear to have been carried into practical operation, does not speak favorably for their efficiency. It does not, however, appear improbable that considerable aid may be afforded to the metallurgist from a slight modification of some of the preceding processes. Such advantages would seem to be indicated in the following general direction, viz.:

(1) The direct formation of certain alloys by making the constituent ingredients thereof the terminals of a sufficiently powerful electric source, and combining them directly through the agency of the voltaic arc taken between them.

(2) The more intimate union of the constituent ingredients of alloys by passing electric currents through them while in the melted state by dipping therein inert electrodes.

(3) The purification of metals by a species of electrolytic separation, by passing electric currents through them while in a melted condition by dipping therein electrodes capable of uniting with the electro-negative, or electro-positive impurities, or with both.

That some of the processes as described, without any modification whatever, may have proved of a considerable value, would appear to be quite probable.

Central High School,
Philadelphia, *January 21, 1888.*

JETTIES FOR IMPROVING ESTUARIES.

By Lewis M. Haupt, A.M., C.E., Professor of Civil Engineering, University of Pennsylvania.

For centuries the efforts of engineers have been directed towards reducing the heights of the bars which obstruct the entrances to harbors or rivers on alluvial coasts.

They have attempted to apply the concentrated ebb stream to a limited portion of the bar by means of jetties reaching, at times, above high water, in other cases to half tide, and again being entirely or partially submerged. As the resources of the profession appear to be limited to such constructions, aided by dredging, and as the practice seems to be to follow the precedents furnished by experience, it will be instructive to note the results of these structures upon the entrances where deeper water is desired.

In considering the results produced it will be found convenient to classify the structures, according to their conditions of exposure, into three groups:

(1) Where there are tidal fluctuations of considerable magnitude, with but small interior tidal reservoirs and little or no fresh water drainage.

(2) Where the tidal oscillations are small and the land discharge large; and

(3) Where there is a considerable fresh water volume débouching into a tideless sea or lake.

In the first class, where the attempt has been made to improve the channel by scour between jetties, the works have in general proven unsuccessful, as they have invariably resulted in advancing the general shore line, and in pushing the bar further to sea without material increase of depth over its crest. This inherent defect has been partially overcome by constructing large sluicing reservoirs contiguous to the channel and by the frequent recourse to dredging.

In justification of such works for tidal estuaries in this country, frequent reference has been made to the success of the jetties at

the Sulina mouth of the Danube; to the various harbors on our great lakes; to Swinemunde, on the Baltic, and to the South Pass, on the Gulf of Mexico, but the instances are unfortunate for the reason that the seas are tideless or nearly so, and the volume of fresh water discharge is very large as compared with the tidal prism, thus placing them all in the second or third group.

The only case in this class that has come under our observation which has approximated to a successful result, is that at the mouth of the Liffey, at Dublin Harbor, where the improvement is largely due to a gap of 600 feet left in the north wall at its shore end through which the ingress of the flood tide is facilitated. To this extent it confirms the theory and plans which are suggested herein for the difficulties encountered in such cases.

Extracts from a paper read May 20, 1879, by Jno. Purser Griffith, Assoc. M. Inst., C.E., on "The Improvement of the Bar of Dublin Harbor by Artificial Scour:"

"Mr. Giles recommended that an opening should be left at the shore end of the proposed wall 600 feet wide, to allow of a free passage for the tidal waters north of the Green or Bull Island, as the sand island on the North Bull was called. This opening had been proposed by Capt. Corneille in 1802; but at that time the Directors General of Inland Navigation feared that the tide flowing through this opening would carry sand from the North Bull into the harbor, and that the injury thus done to the port might more than counterbalance any advantage to be gained by the opening.

"In 1835, Sir Wm. Cubitt reported upon the state of the harbor. Referring to the improvement of the bar, he says: 'The great increase of depth and improved channel over the bar, I attribute entirely to the erection of the Great North Wall, a measure founded upon sound principles and carried into effect in a manner well calculated to effect the desired purposes, viz., that of checking the influx of sand upon the flood tide from the North Bull into the harbor and giving an increased impetus at the ebb tide by means of narrowing the stream, and confining it in a direction suitable for keeping open the best channel, the effect of which is already shown by an increased depth of five feet over the east bar since the erection of the Great North Wall.'"

Capt. Washington, in his report, written in 1845, on the harbor of Dublin, as one of the Tidal Harbor Commissioners, referred to the Great North Wall as follows:

"The propriety of this measure, which involved so heavy an expenditure, has been a subject much controverted amongst persons connected with the port, but it is believed that there is now but one opinion as to its beneficial effects, and that the plan evinced both good judgment and skill."

There are few, if any, cases of a bar and entrance channel to any harbor

being increased in depth like that of Dublin, viz.: about seven feet in thirty years, and great credit is due those who designed as well as those who executed works which have achieved so important a result.

The improvement of Dublin Harbor entrance ranks second to none. There is no other example, so far as the author is aware, of the construction of an artificial estuary for scouring purposes which has proved so successful.

DISCUSSION.

Mr. Abernethy, Vice-President, said he thought attention should be directed to the construction of works which would tend to increase the tidal volume, and at the same time to prolong the action of the outgoing currents from the period of half ebb towards low water.

Mr. Bergeron stated that it was very difficult, almost impossible, to dredge sand bars in an open sea.

Mr. Vernon-Harcourt, that to diminish the tidal capacity within a harbor was the worst thing that could possibly be done.

Mr. Griffith said: "Prior to the construction of the Great North Wall the ebb of a spring tide attained a velocity of one and one-fourth miles per hour across the bar, while at present it reached nearly three and one-fourth miles, showing an increase of about two miles per hour." He did not believe that very high velocities were efficient. Several instances might be named in which high velocities were attained, and yet the scour was a failure.

Mr. Stoney thought that though there might be some doubt as to the authorship of the Great North Wall, there could be none as to its complete success.

In the application of the jetty system to the alluvial harbors of the Atlantic and Gulf Coast, an effort has been made to compromise the conflicting requirements of *free ingress to flood* and concentration of ebb by building submerged structures of brush mattresses, with a rip-rap covering. These jetties subsided rapidly, and in some instances shrank over fifty per cent. of their original volume, making them cost more than stone. Their effect in an incomplete state has been to push the bar seaward and to induce a scour along their edges, requiring protection by spur dykes without at the same time materially increasing the depths over the bar.

For the ports on the Gulf, the question is one of vital importance. The state of Texas alone embraces 237,504 square miles, yet the best harbor, which is found at Galveston, has but thirteen feet of water and a mean rise of tide of only 1·1 foot. Whatever plan gives greatest promise of a successful issue should be the one applied, and it must be based upon a knowledge of the resultant forces operating at that entrance as revealed by a comparative study of its physical hydrography.

Without giving a critical, detailed statement of these conditions, a succinct history of the changes will indicate the main points to be considered in designing a structure applicable to this site.

HISTORY.

The U. S. Coast Survey of 1867 revealed a remarkable progression of the shore-line and islands to the southwestward and a shoaling of over three feet on the inner bar. To resist these changes, the U. S. Engineers began the collection of data by surveys in 1868, and upon these have submitted several plans for accomplishing the desired object. McAllister's hope was in dredging; Howell's in parallel jetties of gabions, which are now beneath the sands; Mansfield and the Boards of Engineers trusted to submerged jetties, one of which was partially built; Eads believed that high convergent jetties would produce the required result, and in this view the permanent Board of Engineers has at length acquiesced as the only proposed plan that has not been tried. So a score of years have passed and there is virtually no better water, yet in the Report of January 21, 1886, the Board of Engineers says: "Deeper water on the bar is needed, and the question to be considered is, how that deep water can be obtained. The methods are two: (1) by dredging alone; (2) by using tidal scour between jetties, aided, if necessary, by jetties. As to the first method, it has already been tried unsuccessfully." * * * "The second method would include the obtaining of a deep channel way to be protected by jetties from the deteriorating effect of wave action, and from the influx of sand, and the maintenance of that channel way by the aid of tidal scour, supplemented, if found necessary, by dredging. The jetties should be so placed as to secure the greatest tidal scour practicable, without seriously injuring the interior harbor, and without greatly endangering the safety of the jetties against undermining or of Galveston Island from overflow in great storms. The greatest scouring effect will be obtained, and the greatest security against undermining, by making the jetties tight and by raising them above high water." * * * "Cost of jetties complete to thirty-foot curve, $7,000,000, their aggregate lengths being nearly 54,000 feet. This estimate supposes that the money is freely supplied."

UNCERTAINTY AS TO RESULTS.

When so large an amount is involved (although it is small as a measure of the interests at stake) we should expect to find a reasonable amount of confidence as to the results to be obtained. It will be seen that the project is dependent upon tidal scour, and that this can only be obtained by concentration of the *ebb* currents upon some point of the bar. To effect such concentration the flood tide must be freely admitted to the inner bay, so it may be "filled at every influx of the tidal wave," for if the flood is diminished in volume, the ebb will be likewise reduced, and if a part, say one-half, of the gorge between Fort Point and Bolivar Island were filled up, it would restrict the flood in nearly the same ratio. High jetties would produce such an effect by cutting off the incoming tide from the funnel-shaped entrance of the gorge, and practically transferring the latter to the crest of the bar where the velocities are much less. That such a result is anticipated by the Board appears from their report just referred to, where in discussing the

WIDTH BETWEEN JETTIES,

they say, "Such a jettied channel offers more resistance to inflow than does the present entrance; reduces the present tidal prism about one-third; allows the bay to fill more slowly than the present entrance does, and hence gives greater differences of level than that given by the present entrance;" and they add: "Diminishing the interval between the jetties from 7,000 to 3,500 feet, changes the difference of level between the bay and gulf but slightly. Through the opening of the same depth and double width, about twice as much water will flow in and out, but as it flows through a double cross-section its velocity is nearly the same, * * and the depth will be nearly the same." Again, on page 18, the Board says, "the jetties will diminish the freedom of inflow at Galveston."

Another Board, composed in part of the same officers, reported with reference to the jetties at Sabine Pass, in these words: "Now if jetties are built from the shore, 1,800 feet apart, as proposed, across the bar to deep water, the pass is virtually prolonged three and one-half miles, and its mouth transferred to the same distance seaward. The funnel-shape of the entrance way will be lost, and the surface slope of the channel of this elongated pass will be diminished, both of which changes will decrease the tidal flow."

From these extracts it would appear that the authorities are agreed that concentration of ebb for tidal scour can only be obtained at the expense of the flood volume, and that the successful application of jetties depends upon a proper adjustment of the area and length of the channel between the jetties to the tidal volume of the inner bay.

GREAT WIDTH BETWEEN JETTIES.

Upon this point Capt. Jas. B. Eads says: "The slope (producing scour) results from the difference of level between the surfaces of the gulf and the bay. Any one can see that the more freely the water can flow from one to the other, the less difference will there be between the heights of their respective surfaces, and consequently the less will be the slope of surface through the channel between them, and the less will be the current velocity. This is certainly the very opposite of what we *must have* to produce deepening. Hence, it is evident that *large openings* and a freer communication with the bay through them, and over low, submerged jetties, are precisely what we do not want."

Hence, while the doctors disagree, the one condemning narrow, the other wide passes, we may leave them to their opinions and read the lessons of experience from

THE BOOK OF NATURE.

When large inner bodies of water are connected with the ocean by small inlets, it becomes impossible for the inflowing tide to fill them to the level of the ocean during the time of the rise or fall.

A small volume may pass in when the outer level is above the inner, and *vice versa*, but the general level of the water in the bay or sound will not be sensibly affected, and it will stand at about the height of mean tide. The flood will then begin to flow in at half tide, and will have its maximum velocity at "high-water-stand," and the ebb will occur between mid-tide and low-water, but as the inlet is small and the inner prism large, the currents will be too feeble to produce marked effects. This action is very perceptible at Albemarle and Pamlico Sounds, where, according to the United States Coast Survey Report of 1862, p. 45, it is said, "the basin being nearly tideless, has its surface lying at about the mean level of the sea—that is, at the half-tide plane—and it is upon this plane that the currents of the inlet must take the initiative. Moreover,

the maximum velocities must occur when the greatest contrasts of height between the ocean and the sound obtain; that is, at *high water* for *flood* and at *low water* for the *ebb*." The more the inlet is contracted, therefore, the less will be the tidal oscillation upon which the inner bay depends for its currents to maintain its channels. *Every construction on the bar becomes more or less of an obstruction to the tidal ingress*, and, consequently, neither high jetties nor submerged jetties will satisfy the conditions.

THE PROBLEM

is to discover a form and position of structure which will not seriously oppose the flood ingress, but which will utilize it for scouring over the bar; will cause it to deposit its load of sand outside the crest and not carry it into the channel; will concentrate a large portion of the ebb for effective work on the bar; will furnish every possible facility to vessels entering the port in all stages of weather, and prove at the same time an aid to navigation.

A solution which appears to fulfil all these fundamental conditions is herewith submitted by the author. It is based upon the fact, which is so frequently observed and referred to by the engineers in charge of improvements along the Gulf coast, that the resultant direction of all the forces acting year in and year out, is to the west and southwest, or, in other words, our coast-line drift is rolling in that direction; and upon the further fact that the flood is the potent agent which lifts up the bars in front of our entrances, which the superficial and enfeebled ebb is unable to cut down. For example, the report on Pass Cavallo says, "its history, like that of other entrances on this coast, showed a steady deterioration as a harbor and a constant shifting of the channel to the south and west. Yet the jetty is built on the *south* side of the channel, where it will catch the sand and drop it in the channel and fill it up as surely as a snow fence placed to the leeward of a cut will aid in filling the cut. It thus requires more work of the ebb, which must carry this sand out to the gulf beyond the end of the jetty, and thus extends the bar rapidly in that direction. Estimate for this pass, $1,039,280.

For Arkansas Pass the report says: "And its history, like other entrances on this coast, shows a constant movement of its channel to the south, with progressive shoaling therein and enlargement of

the Gulf Bar." Estimate $1,200,722.75. And the *south* jetty is again built to catch sand and obstruct the natural channel. Again at Brazos, where the estimated improvements were to cost $328,000, "approval was given to so much of the project as covered the construction of the *south* jetty," although "the harbor within was obstructed directly across the mouth of the pass by a bar in the *usual curved form*," etc.* At Sabine Pass, estimated to cost $3,177,606.50, the *west* jetty was built first and made a shoal on its east side, and in 1885 the crest of the bar had been moved seaward 1,900 feet, and it is said, "It is perhaps impossible to decide as to the amount of influence the work done has had upon the depth of water across the bar." And so at Galveston, the same experience is repeated and the same comments may be made as to effects produced.

WHAT IS TO BE DONE?

Evidently to barricade the sand by a break-water of a concave, curved form, so as to decompose the flood and precipitate its burden of sand outside the channel, and having a straight inshore flank to aid the flood in cutting a beach channel, short, deep and direct between the bar and the shore, not by parallel or convergent jetties, but by a *single line of works having a total length of less than half that proposed for the high jetties, costing less than half the amount and producing much greater effects* in removing these serious obstructions to commerce. Thus nature will be aided in her efforts to build up an island or middle ground with a channel on either hand and a lee-way for all conditions of storm or tide.

* The engineer in charge has recently reported with reference to this entrance that, "The work already done has disappeared without having any effect on the bar."

ISOLATION OF FLUORINE.*

By A. E. Tutton.

One of the most difficult problems of modern chemistry has at last been solved satisfactorily. After three years of incessant labor, occasionally interrupted by temporary feelings akin to despair, M. Henri Moissan has at length isolated in considerable quantities that most baffling of elements—fluorine, and has been enabled to determine its principal properties. The experiments themselves are among the most interesting ever performed, and their details, as described by M. Moissan in the December number of the *Annales de Chimie et de Physique*, form the most fascinating reading. They must of necessity have been extremely costly, for by far the greater portion of the apparatus employed was constructed of platinum, and it is not often that one hears of a platinum tube 80 centimetres long and of 1½ centimetres diameter being destroyed in each experiment, as happened in the earlier stages of these researches.

The isolation of fluorine has formed a worthy object of the attention of chemists ever since the first remarkable experiments of Sir Humphrey Davy, who was rendered dangerously ill by being exposed to the corrosive fumes of hydrofluoric acid. Although Davy was not successful in obtaining free fluorine, yet he brought clearly to light the nature of hydrofluoric acid, and proved it to consist of hydrogen combined with an unknown but extremely active element—fluorine. The history of all the attempts which have since been made to effect the preparation of free fluorine might occupy a volume, and it will therefore only be necessary to refer to the later work of our countryman, Gore, who, in 1869, published his researches upon the electrolysis of hydrofluoric acid, and of certain fluorides, and left our knowledge of the acid itself in a most complete state. M. Moissan, working in the laboratory of M. Debray, now steps in and achieves the result so ardently sought after during the last eighty years—another example of the irresistible power of human perseverance.

* London *Nature*, **37**, 179.

In the light of the experience gained by former experimenters, it appeared that the action of a powerful electric current upon the compounds of fluorine with the non-metallic elements, such as hydrogen, phosphorus and arsenic, would be most likely to yield the desired result; knowing also that fluorine must be an extremely energetic substance, it was absolutely essential to work at very low temperatures. Hence M. Moissan's first attack was made upon the fluorides of phosphorus and arsenic, but finding these to be practically impregnable, he diverted his attack, guided by certain indications afforded during his first attempt, upon hydrofluoric acid itself. Finding, however, that pure hydrofluoric acid is an exceptionally bad conductor of electricity, as has been stated by other workers—that even a current from fifty Bunsen cells would not pass through the liquid—he eventually, after several essays, succeeded in converting it into a conductor by dissolving in it a quantity of the double fluoride of potassium and hydrogen. On passing the current from twenty Bunsen cells through the now conducting medium, hydrogen immediately commenced to be evolved at the negative terminal, while fluorine was with similar rapidity evolved at the positive pole, and exhibited its tremendous activity upon everything that came near it: burning up hard crystalline silicon like tinder, setting fire to organic matter, and forming fluorides with incandescence with many other elements.

Having thus indicated the general course of these researches, it will no doubt be interesting to follow M. Moissan during the carrying out of his principal experiments.

The first series consisted in examining the action of electric induction sparks upon the gaseous fluorides of silicon, phosphorus, and arsenic. The gases were introduced into glass eudiometer tubes standing over mercury, and the spark was passed between two platinum wires connected with an induction-coil actuated by a few Grenet or Bunsen cells. On introducing dry silicon tetrafluoride, SiF_4, and passing sparks for an hour, no decomposition was effected, the result being discouragingly *nil*. Dry phosphorus trifluoride, PF_3, however, behaved quite differently, phosphorus being deposited upon the inner wall of the tube; but the fluorine liberated at once combined with the residual trifluoride to form the more stable pentafluoride, PF_5. Some time ago this penta-

fluoride of phosphorus was prepared by Prof. Thorpe, who also submitted it to the action of the induction spark, unfortunately without effecting any decomposition. Precisely the same result has been arrived at by M. Moissan, using a 0·04m. spark; but on obtaining sparks 0·2m. long, a rapid etching of the walls of the glass tube occurred, and the meniscus of mercury entirely lost its brilliancy. After an hour's duration the experiment was concluded, and the apparatus allowed to cool, when it was noticed that the volume had diminished; moreover, the gas was found to have changed its properties, yielding a precipitate of silica in contact with water, while the residual gas consisted of the trifluoride of phosphorus. Hence $PF_5 = PF_3 + F_2$, which latter forms, with the glass, silicon tetrafluoride, and, with the mercury, fluoride of mercury. So here again the experiment was disappointing, and although fluorine was for the moment liberated, this method was certainly not suitable for the preparation of free fluorine.

Fluoride of arsenic, AsF_3, the next fluoride experimented upon, was first prepared by M. Dumas, who was severely injured in the experiment. It is a liquid which boils at 63° C., and may easily be maintained in a gaseous condition by use of a steam jacket, and submitted to the action of the spark. It is, however, a most disagreeable substance to work with, as it produces most terrible sores when, by any mischance, it comes in contact with the operator's skin. On passing sparks through it for an hour, as in case of the pentafluoride of phosphorus, the platinum wires became covered with a black incrustation of arsenic, while the walls of the tube were strongly corroded. On testing the gas, it was found to contain a large quantity of silicon tetrafluoride mixed with a smaller quantity of free fluorine, which displaced sufficient iodine from a solution of potassium iodide to give a good coloration to several cubic centimetres of chloroform. Clearly, progress was being slowly made, though still far from the isolation of fluorine.

And now a remarkable experiment of a new type was performed. It had been noticed that, on passing an electric current through a platinum wire in an atmosphere of phosphorus trifluoride, the platinum fused owing to the formation of a fusible phosphide of platinum; at the same time the glass of the containing vessel was etched and the mercury attacked. So the experiment was repeated on a grander scale. A quantity of spongy platinum, pre-

viously washed with hydrofluoric acid and calcined, was placed in a platinum tube 80 cm. long and of 1·5 cm. diameter; that portion of the platinum tube which required to be heated was incased in a second outer tube of glazed porcelain, so that between the two a current of nitrogen could be kept circulating, and so prevent access of furnace gases. The tube was then heated in a furnace, and pure hydrogen passed through it for some time to remove all other gases; afterwards pure nitrogen was substituted, and finally phosphorus trifluoride. After passing a short time, the current of fluoride was suddenly stopped with a most singular result: a partial vacuum was caused, owing to absorption by the platinum.

When, however, the current of trifluoride was passed more rapidly, a small quantity of pentafluoride was formed; the fluorine liberated, when the absorption of phosphorus by the platinum occurred, having combined with the trifluoride just as in the spark experiment. But, on examining the gas which passed out of the tube under these conditions, it was found to liberate iodine from potassium iodide, attack mercury, and etch glass. In fact, it was proved that free fluorine was liberated, and mostly absorbed by the platinum, causing the diminution of pressure on stopping the current, but being more or less carried away when the current was more rapid. The fluophosphide of platinum formed was found to contain only seventy to eighty per cent. of platinum, and the formation of this substance was so rapidly effected that every experiment required a new tube. The action of pentafluoride of phosphorus upon platinum was next tried, and with still more encouraging results. On sweeping the tube, heated in a coke blast furnace, with a rapid stream of the pentafluoride for some minutes, then moderating the rapidity, and five minutes later again increasing the speed, the issuing gas was found to blacken solid potassium iodide by liberating free iodine, inflame phosphorus, and attack crystalline silicon, glass and mercury. It was, in fact, free fluorine drowned in excess of trifluoride of phosphorus. This was a decided advance, and the outlook was becoming considerably more hopeful.

The next experiments were made with liquid fluoride of arsenic, AsF_3, a quantity of which was placed in a platinum crucible, which served as the negative electrode. A platinum wire, dipping into the liquid in the crucible, and reaching to within five millimetres

of the base, served as the positive electrode. The current from three Grenet cells was then passed through the liquid, causing a deposition of arsenic upon the interior surface of the crucible, but no gas could be perceived at the positive pole. However, on dipping the platinum wire into a solution of starch paste and potassium iodide, blue striæ were at once formed in the solution, showing the presence of a condensed gas sheath of fluorine around the platinum wire. Following up this indication, the current from twenty-five Bunsen cells arranged in series was next employed, and immediately the deposition of arsenic commenced upon the walls of the crucible, while bubbles of gas were evolved around the platinum wire. Unfortunately the action soon ceased, owing to the bad conductivity of the liquid and of the thick deposit of arsenic. The wire, however, was strongly attacked. So attempts were next made to increase the conductivity of the fluoride by the addition of metallic fluorides, and it was soon discovered that the best results were obtained by use of the double fluoride of hydrogen and potassium, HF . KF. It was probably this discovery which led to the grand success with which these efforts were finally crowned, for, as has been previously mentioned, it was by the electrolysis of this double fluoride that M. Moissan eventually succeeded in preparing free fluorine.

Before leaving the experiments upon arsenic fluoride, it may be mentioned that it was eventually electrolyzed in a continuous manner by use of seventy to ninety Bunsen cells, the arsenic liberated remaining in suspension in the liquid, instead of adhering to the tube, but the bubbles were rapidly seen to diminish in size in passing through the liquid, and scarcely a trace of gas escaped; instead of permitting its isolation, the flourine preferred to form a new fluoride, the pentafluoride of arsenic, thus once more baffling the ingenious experimenter.

But success was now not far away. The wonderful manner in which the double fluoride of potassium and hydrogen increased the conductivity of arsenic fluoride determined M. Moissan in employing it for the same purpose in an attempt to electrolyze pure anhydrous hydrofluoric acid. Faraday long ago showed that the electric current will not pass through the anhydrous acid, and Gore more recently came to the same conclusion. The current from fifty Bunsen cells was found by M. Moissan to be absolutely

powerless to penetrate the acid used in these later experiments. But, on dissolving a few fragments of the double fluoride, HF.KF, in the acid, the current at once passed freely, and the experiment thus became possible. The apparatus used in the first attempts with this mixture consisted of a platinum U-tube, of which each branch was closed by a paraffined cork, through which the rods of platinum forming the poles were passed. Upon each branch, just above the level of the liquid and beneath the cork, was soldered a little platinum delivery-tube to lead off the gases evolved. As hydrofluoric acid boils at 19°·4 C., the apparatus was immersed in a bath of methyl chloride, which boils at — 23°, but which could be reduced in temperature to — 50° by driving through it a current of dry air. Hence the electrolysis could be conducted without fear of the gaseous products being drowned in excess of vapor of hydrofluoric acid, and the activity of the liberated fluorine was at the same time moderated. On passing the current, a gas was at once produced at each electrode, a regular evolution of hydrogen at the negative pole, and a continuous disengagement of gas at the positive pole. But still affairs were not satisfactory: crystalline silicon did not take fire when held in the gas coming off from the positive pole; so the apparatus was taken to pieces an hour later, in order, if possible, to find a clue to the source of failure. The paraffined cork at the negative branch was intact, but, behold the mischief, the other was carbonized to the depth of a centimetre; so the liberated fluorine had extracted hydrogen out of the cork, and passed on as hydrofluoric acid. The positive platinum rod was also much corroded. Closely-fitting stoppers of fluor-spar were next tried, coated with melted gutta-percha, but the latter again soon melted on passing the current, and was put *hors de service.* Gum-lac and many other substances were tried, but all to no purpose, and much precious time was lost. Finally, however, the difficulty was overcome by using stoppers of fluor-spar, carefully inserted in hollow cylinders of platinum carrying fine screw threads upon their outer surfaces, which engaged with corresponding threads upon the interior surfaces of the two branches of the U-tube. The platinum rods passed through the axis of each cylinder of fluor-spar: the rods themselves were of square section, of 2 millimetres side and 12 centimetres long, and passed to 3 millimetres from the base of the U-tube; they were made of irido

platinum, containing ten per cent. iridium, which is less attackable than pure platinum. The U-tube consisted simply of a platinum tube, bent twice at right angles, 1·5 centimetres diameter and 9·5 centimetres high, and was fitted with side tubes and immersed in methyl chloride as before.

The pure anhydrous hydrofluoric acid, which was the next necessity, was prepared in the following manner. A known volume of commercial acid was treated with sufficient potassium carbonate to neutralize about a quarter of it, and then distilled in a leaden retort over an oil bath at 120°. At this temperature the fluosilicate of potassium, formed from the hydrofluosilicic acid, contained as impurity in the commercial acid, was not decomposed, and the distillate was therefore free from silica. This distillate was then divided into two parts, and one-half, saturated with pure potassium carbonate, forming neutral potassium fluoride, was then added to the other half, and transformed into $HF \cdot KF$. The double fluoride was then dried at 100°, and afterwards kept for some days in the vacuous receiver of an air pump, containing also strong sulphuric acid and a few sticks of fused potash. When absolutely dry it fell to powder, and was then ready for the preparation of hydrofluoric acid, which was always freshly prepared immediately before each experiment. The dry fluoride was in each case introduced into a recently ignited platinum retort, and maintained at a moderate heat for some time so as to commence the decomposition slowly; the first portions of distillate were rejected, as they would contain the last traces of water. The platinum receiver was then adapted and surrounded by ice and salt; on heating the retort more strongly, pure hydrofluoric acid condensed in the receiver as a limpid liquid boiling at 19°·4, very hygroscopic and fuming in the air.

While the preparation of the acid was in progress, the U-tube and electrodes were drying at 120°. From six to seven grammes of the dry double fluoride were now introduced into the apparatus, the stoppers were screwed in and covered with gum-lac. The whole was then fixed in the methyl-chloride bath, and, until the introduction of the acid, the delivery tubes were connected with desiccators containing fused potash. A constant supply of methyl chloride at — 23° was maintained in the outer cylinder, as a slight rise of temperature allowed of the volatilization of some of the acid.

About fifteen to sixteen grammes of the anhydrous hydrofluoric acid were then gently aspirated into the apparatus, and the current from twenty Bunsen cells allowed to pass, when immediately a regular evolution of gas occurred at each pole. At the negative pole pure hydrogen was evolved, which burnt with its characteristic flame, forming water. At the positive pole was liberated a colorless gas of penetrating and very disagreeable odor, somewhat resembling that of hypochlorous acid, and rapidly irritating the mucous membranes of the throat and eyes. It was no other than pure fluorine itself. All the trouble, all the expense, and all the disappointments were repaid. It must, indeed, have been a supreme moment for M. Moissan.

In order to study its action upon solids, they were placed in small glass tubes, and brought near to the orifice of the platinum delivery tube at the positive side. The test was generally repeated, holding the solids in small platinum capsules.

Sulphur, brought thus near the orifice, at once melted and inflamed; selenium behaved in like manner; as did also tellurium, with incandescence, forming fumes and becoming coated with a solid fluoride.

Phosphorus at once took fire, forming tri-, penta-, and oxy-fluorides. Powdered arsenic and antimony combined with incandescence, the former yielding drops of AsF_3.

A fragment of iodine placed in the gas combined with production of a pale-blue flame; in an atmosphere of iodine vapor fluorine itself burnt with a similar flame. Vapor of bromine lost its color and the combination was sometimes accompanied by detonation.

Cold crystalline silicon at once became incandescent, and burnt with great brilliancy, sometimes with scintillations. On closing the little tubes containing it with the thumb and opening under water, the silicon tetrafluoride formed was absorbed and decomposed with precipitation of silica. Any undecomposed silicon was found to have been fused.

Debray's adamantine boron also burnt in the gas, becoming incandescent and giving off fumes.

Fluorine has a most extreme affinity for hydrogen; they combine in the dark with explosion. In one of the experiments the electrolysis was allowed to continue several hours, so that eventually the small quantity of undecomposed acid remaining in the

U-tube was insufficient to keep the two gases apart; the experimenters were consequently suddenly startled by a violent detonation. The hydrogen and fluorine had combined in the dark at the low temperature of — 23°. The same detonation was afterwards brought about on a smaller scale by reversing the current. On bringing the wide-mouthed delivery tube of a hydrogen generator near the orifice, the detonation at once occurred, and the hydrogen inflamed.

Metals are all attacked with more or less energy by fluorine, forming fluorides. Cold sodium and potassium were at once rendered incandescent. Calcium, magnesium and aluminium acted similarly, in a more modified manner, becoming incandescent when slightly warmed. Powdered iron and manganese, on gently warming, burned with bright scintillations; lead was attacked in the cold, and tin at a slightly elevated temperature. Mercury, as suspected, entirely absorbed the gas, forming yellow protofluoride. Silver at a gentle heat became coated with a beautiful satin-like fluoride, soluble, unlike the chloride, in water. Gold and platinum at 300°–400° became coated with their respective fluorides, which were decomposed again at a red heat, with evolution of free fluorine.

Perhaps the strongest evidence of the intense chemical activity of fluorine is exhibited in its action upon cold potassium chloride: the chlorine was at once expelled, filling the air with its disagreeable odor, and was identified by the usual chemical tests. Chlorine was also expelled from its combination with carbon in carbon tetrachloride.

All organic compounds are violently attacked by fluorine; a piece of cork at once carbonized and inflamed; alcohol, ether, benzine and turpentine took fire immediately in contact with it.

Glass, as might have been expected, is at once corroded by fluorine; some very delicate experiments were carried out with perfectly dried glass, with the same result.

Many other reactions, all interesting and all showing the immense energy with which the atoms of fluorine are endowed, were performed, but one especially ought to be noticed, viz., the action of fluorine upon water. It is a singular fact that, whenever oxygen is liberated in the cold, there is a great tendency to form ozone: hence when fluorine is attempted to be collected over water, the gas collected is not fluorine, but ozonized oxygen; water is decomposed

by the fluorine forming hydrofluoric acid, while the oxygen is set free, and a considerable quantity of it is converted into the more condensed form of ozone.

On taking the apparatus to pieces after each experiment, the hydrofluoric acid remaining was found to contain a small quantity of platinum fluoride in solution, and a black mud consisting of a mixture of iridium and platinum in suspension. The negative electrode was not attacked, but the platinum rod forming the positive pole was eaten away to a point, so that one rod only served for two experiments. The average delivery of gas was about 1·5 to 2 litres per hour.

With regard to the chemical processes involved in the electrolysis, it appears probable that potassium fluoride is first decomposed into fluorine, which is evolved at the positive pole, and potassium, which decomposes hydrofluoric acid, liberating its equivalent of hydrogen at the negative pole, and re-forming potassium fluoride, which may again be electrolyzed. Hence a small quantity of the double fluoride can serve for the decomposition of a comparatively large amount of hydrofluoric acid.

The double fluoride HF. KF is very soluble in hydrofluoric acid, forming a crystallizable compound, richer in hydrofluoric acid than HF. KF, and which gives off no acid vapor at the boiling point of the anhydrous acid, 19°·4. It is this compound which one ought to seek to obtain for electrolysis, as it is very soluble in excess of acid, forming a liquid of good conductivity.

The double fluoride, HF . KF, itself, was finally electrolyzed by M. Moissan. It fuses at 140° to a colorless liquid which is quite suitable for electrolysis. The experiment was performed, as before, in the platinum U-tube, and, on passing the current, fluorine was again liberated at the positive pole, and at once set fire to crystalline silicon; but the platinum was strongly attacked, so the experiment was stopped in order to save the tube. On plunging a couple of platinum wires connected with the battery into a quantity of the fused double fluoride contained in a platinum crucible, gas was evolved in abundance at each pole, and on bringing the wires in contact, even in the dark, detonation occurred, owing to the combination of the evolved hydrogen and fluorine. At the same time the platinum wire from which the fluorine was evolved was almost entirely eaten away.

In concluding these remarkable researches, which have happily terminated so successfully, M. Moissan discusses very fully the question of the identity of the gas liberated at the positive pole with the element fluorine; and there can be no doubt that he has completely proved this identity, at the same time showing that fluorine occupies the place of honor as the most intensely active chemical element with which we are at present acquainted, and that it assumes its rightful position, theoretically destined for it, at the head of the group of halogens.

THE JAPANESE MIRROR.—II.

F. E. IVES.

(*The Substance of Remarks at the Meeting of the* INSTITUTE, *held Wednesday, February 15, 1888.*)

A few days ago I discovered, in a pawnbroker's window, a Japanese mirror, which is interesting because it is of exactly the same size, and has the same general appearance as that which I showed at the November meeting, but has the magical feature so very imperfectly developed as to make it evident that no intelligent effort was made by the workman to bring it out. The magical image is confused and imperfect, yet so similar in character to that produced by the other mirror as to leave no room for doubt that, although not intelligently developed, it results from substantially the same causes.

There are several peculiarities about this mirror which confirm the explanation that I gave; but it appears that that explanation was already known to some, and so well established as to require no further experimental demonstration. Prof. Wm. A. Anthony, whose lecture on electrical measurements you will remember, assured me that that explanation was made to him in 1881, by Duboscq, of Paris, who then manufactured imitations of the Japanese mirrors, and sold them as curiosities. I doubt if it ever appeared in any publication printed in the English language.

Now, what interests me most in this particular mirror, is the fact that it appears to have been made by a workman who tried to imitate and improve upon the productions of another, and nearly

destroyed the magical feature through his efforts to improve the appearance of the mirror. The design in relief at the back, although showing the same objects, is far more elaborate and detailed than that of the first mirror, and this very elaboration of design, so evidently intended to make the mirror more attractive to the eye, is calculated, both by its character and distribution, to produce the indistinctness which we see in the magical image. The first mirror has broad spaces between those figures which show plainest in the magical image, but this one has the corresponding parts filled up by figures representing clouds, details of foliage, etc., which support the tympanum of the mirror just where it ought not to be supported in order to have the grinding and polishing operations bring out the more important figures so that they will show distinctly in the reflection.

Still another Japanese mirror has been handed in, this evening, by Mr. Outerbridge. It has the same faults as my own, but in a far greater degree. The figures at the back are so closely crowded together that I doubt if any of them will be distinguishable in the reflection.

[A trial of this mirror showed that the magical feature was practically absent.]

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE CYCLOSTYLE AND DUPLICATING APPARATUS OF THE PENNSYLVANIA CYCLOSTYLE COMPANY.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 1, 1887.

The Sub-Committee of the Committee on Science and the Arts, constituted by the FRANKLIN INSTITUTE of the State of Pennsylvania, to which was referred for examination the

CYCLOSTYLE AND DUPLICATING APPARATUS OF THE PENNSYLVANIA CYCLOSTYLE COMPANY,

Report, That the cyclostyle is a species of stylus which perforates a specially-prepared paper, and makes of it a stencil; the stencil is stretched in a frame, and by passing an inked roller over the writing or drawing, a large number of copies can be produced. The details of the process are similar to the duplicating process of

T. A. Edison, the "electric pen" of the latter being replaced by the much simpler implement, called the cyclostyle.

This consists of a minute wheel with teeth, or ridges on its periphery, mounted on an axis carried by a holder or handle similar to a lead-pencil. In writing, it is held the same as a pen or pencil, and lines of minute perforations are made through a thin waxed paper placed upon a hard, plain surface like a tin plate.

The paper used is very thin and tough, and is made from bamboo fibre, and is thinly coated with paraffine wax, so that a letter or word once written on the stencil may be erased by rubbing the wax smooth with the thumb nail, and corrections in the writing can thus easily be made.

The stencil holder or frame is a great improvement over those which have heretofore been in use for the same purpose. Two frames are hinged together; in the sides of one is a groove, and upon the other is a tongue, which corresponds to it, and the two when pressed together clamp the paper so as to stretch it taut and perfectly even like a drum-head. This ensures a clear copy, as the stencil does not move while the inked roller is upon it. Heretofore it has been necessary to fasten the stencil by small clamps, first at the top, then at the bottom, and then at the sides, and the result was seldom satisfactory.

What the inventors, David Gestetner and Augustus D. Klaber, claim as new, are the perforating instrument, the waxed paper and the clamping frame above described.

But little practice is required to enable a person to write quite rapidly with the cyclostyle, and the ease and rapidity with which the stencils can be placed in the frame and copies made from them, take away the principal objection to the use of duplicating processes of this character.

E. ALEX. SCOTT, *Chairman*,
FRED. E. IVES,
H. R. HEYL,
W. M. MCALLISTER.

January 4, 1888.

Amended by the recommendation of the award of "THE JOHN SCOTT LEGACY PREMIUM AND MEDAL," and as so amended, adopted.

WM. D. MARKS, *Chairman.*

I certify that the above is a true copy from the records.

WM. H. WAHL, *Secretary.*

CORRESPONDENCE.

LIMITING NUMBERS OF GEAR TEETH.

A Disclaimer by PROF. MACCORD.

In the last paragraph of Mr. Geo. B. Grant's paper on the "Limiting Numbers of Gear Teeth" (see February issue of this JOURNAL), is found the following in relation to the involute system.

"Thus when recess equals two-thirds of the pitch, we find that the smallest possible pinion has 5,300 teeth, and that no smaller gear will drive anything. This pinion will drive any gear not smaller than that determined by (12), and it will drive any internal gear that will not interfere with it."

So far good; but this foot-note is appended, viz.: "Prof. MacCord states that the rack is the minimum follower for this minimum driver; see section 243 and the tables of section 276 of his *Kinematics*. * * * * * Prof. MacCord claims that I have here misrepresented him; but his language is plain, and will bear no other interpretation than that his tabulated followers are the least possible followers for the given drivers."

	DRIVERS.	FOLLOWERS.	
Involute System.	**5·30**	∞	Recess = 2/3 Pitch.
	6	10	
	7	9	
	9	8	
	12	7	
	28	6	
	∞	**5·36**	

The portion of my table to which immediate reference is made is very small, and I here insert it in full. As to the *whole numbers*, the above interpretation of my language is correct, but "section 243" contains no allusion whatever to the fractional numbers (such as 5·30, 5·36, etc.).

No explanation was considered necessary: these numbers, indicating in each case the *least possible driver* and the *least possible follower* for a rack, being printed in a conspicuously distinctive type, I thought, and I still think, their meaning obvious beyond the possibility of misunderstanding.

Reference to section 243 being fruitless, then, the following is found in section 247: "the exact limiting radius of a pinion which can just drive a rack, is 5·58; * * * * * when the driver becomes a rack, the value of this radius is 9·83."

Comment is needless; I, therefore, beg summarily to say that I have never made, implied, nor imagined the statement that "the rack is the minimum follower for this minimum driver," as asserted by Mr. Grant in the foot-note above quoted.

CHARLES W. MACCORD.

STEVENS INSTITUTE OF TECHNOLOGY,
HOBOKEN, N. J., *February 29, 1888.*

THE LIMITING DIAMETER OF DESCRIBING CIRCLES FOR TEETH OF ANNULAR WHEELS.

The Committee on Publication of the FRANKLIN INSTITUTE.

GENTLEMEN:—It has been called to my attention several times during the last two or three years, that the valuable book on "Kinematics," written by Prof. C. W. MacCord, contains a discussion of "the Limiting Diameter of Describing Circles for Teeth of Annular Wheels," in which he practically claims to be the original discoverer of the law of kimematics bearing on that point. It has occurred to me that it might be appropriate to call attention in your JOURNAL to the fact that you published an article from my pen, covering a demonstration of that law, in your issue of January, 1877.

From the fact that Prof. MacCord's book appeared several years later than this date, it would seem, in the absence of evidence to the contrary, that he was not aware of your previous publication ot the matter. At the time of writing, I sent the discussion to you, with fear that what seemed to me to be an addition to our knowledge of laws of mechanics, might be shown in your next number to be old to the world. It is gratifying, therefore, to have such good testimony as the above appears to be to the originality and importance of the discovery. ALBERT K. MANSFIELD.

280 BROADWAY, NEW YORK, *February 13, 1888.*

OBITUARY.

JOSEPH EASTBURN MITCHELL.

The subject of this sketch was born in Philadelphia, in the old district of the Northern Liberties, on the 3d of August, 1817. He died on the 5th of October, 1887, in his seventy-first year. His ancestors both on the paternal and maternal side were English, and were long settled in America. His father, JAMES MITCHELL, was, in his day, a prominent master-builder, and a member of the Carpenters' Company of Philadelphia. The father of JAMES MITCHELL, and the grandfather of the subject of this memoir, was BENJAMIN MITCHELL, who married SUSANNAH WILSON, a granddaughter of THOMAS SAY, who is remembered as a distinguished naturalist, and one of the founders of the Academy of Natural Sciences.

On the death of his father, which occurred in 1851, JOSEPH E. became the successor of the firm of JAMES MITCHELL & SON, and carried on the business of importing and manufacturing grindstones and grindstone fixtures (founded by his father, JAMES, in 1810) until his death. As evidence of his careful and systematic business habits, it will be sufficient to say that, notwithstanding his devotion to many public duties, he was never involved in financial difficulties, but, on the other hand, increased many-fold the business that he had inherited from his father. Shortly after assuming control of the business, he erected the large factory at Beach and Green Streets, for the storing and finishing of large grindstones. He introduced, from time to time, substantial improvements upon the fixtures in use, and invented, among other things, a valuable tool for trueing grindstones. His business enterprise was manifested in the notable displays of his manufactures at the World's Fair in Vienna in 1873, and in Philadelphia in 1876. The Tuscan Column, built up of grindstones, will be recalled by every visitor to our Centennial Exhibition, as one of the most cleverly-devised and striking exhibits in Machinery Hall. The collection contained thirty-eight varieties of grindstones, including specimens of all the best known grits of Europe, collected for the purpose by WILSON MITCHELL, his son.

The instructive character of this exhibit, having attracted the attention of the late Professor SPENCER F. BAIRD, then the Secretary of Smithsonian Institution, and the head of the projected National Museum in Washington, he decided to make a collection of the materials used in the arts for grinding purposes as one of the features of the Museum, and, to this end, invited and secured the co-operation of MR. MITCHELL, who entered warmly into the project. In carrying the project into execution, a circular was issued to all manufacturers of grindstones in the United States and Europe, whose addresses could be obtained, inviting each to send to JOSEPH E. MITCHELL specimen stones in the rough to be finished by him, and sent to Washington for permanent preservation in the grindstone section of the National Museum. The scheme also contemplated the preparation of thin sections of the various grits, scythe-stones, oil-stones, whetstones, etc., thus collected, for microscopic study of the texture and other physical qualities upon which the value of these materials in the arts depends. As the direct or indirect result of this effort, the National Museum has come into possession of a large and instructive collection of these materials.

One of MR. MITCHELL'S distinguishing personal peculiarities was his love of fruits and flowers, and the warm interest he felt in everything that contributed to the cultivation of these innocent and refining pursuits was manifested by his active co-operation in the work of the Pennsylvania Horticultural Society and the American Pomological Society. Of the first named Society, he was twice the President, and occupied that office at the time of his death, and he took a prominent part in the biennial meetings of the latter.

In 1873, the Councils of Philadelphia authorized the appointment of a Commission "to represent the City of Philadelphia at the Vienna Exposition, and to collect such information as might aid * * * in carrying out the objects of the Centennial Exhibition." Of this Commission, MR. MITCHELL was appointed the president, and the results of its work appear in a report presented to MAYOR STOKLEY in December of the same year, and which embodied a number of eminently useful suggestions. Of these, it may be interesting to refer to one, which proposed "the erection of a suitable building to receive the mementos which would be

offered at the close of the Exhibition, many of them of great historical interest, and all of them useful as the nucleus for the formation of a Museum of Art, Science and Manufacture." The South Kensington Museum was indicated as the type of this institution, and it was further suggested that in the construction of the Memorial Hall this object should be kept in view. These suggestions, without doubt, originated with JOSEPH E. MITCHELL, and whatever credit may be attached to the formulation of a proposition, which has since assumed concrete form by the establishment of the "Pennsylvania Museum and School of Industrial Art," should properly belong to him. His deep interest in the subject was shown in other ways. He warmly advocated it in an address before the FRANKLIN INSTITUTE, in the course of which he gave an account of the work of the English institution, and described the benefit that would follow the foundation and growth of a similar one in Philadelphia. He was invited, in 1875, to participate in the organization of the Museum, and at the meeting held in pursuance thereof, he recommended the title "Museum of Industrial Art." He was nominated in the same year, when its organization had been completed, to represent this INSTITUTE in the Board of Trustees, but withdrew in favor of the then Secretary of the INSTITUTE. In 1878, he was elected by the House of Representatives to represent the State of Pennsylvania in the Board of Trustees and served in the office by successive re-elections for five years, and manifested his interest in its work by service on the Building Committee (of which, for a time, he was the Chairman), on the Executive Committee, the Committee on Art Industries, and the Committee on Finance.

MR. MITCHELL was one of the corporators of that excellent charitable institution, the "Hayes Mechanics' Home," of which he was also, for many years, one of the managers. He was an intelligent and liberal patron of music, and was one of the originators and guarantors of the Philadelphia Music Festival, and of its outgrowth, the Philadelphia Musical Society or Chorus (still in existence). He was likewise an active member, from its foundation, of the Utopian Club, a local society of professional and amateur musicians.

MR. MITCHELL'S active connection with the FRANKLIN INSTITUTE dates from the year 1867, when he was elected to membership. He became a life member in 1880. He was elected to the

Board of Managers in 1873. In 1876, he was elected one of the Vice-Presidents, which office he occupied down to the time of his death. He served during most of this time as a member of the Committee on Exhibitions. Until within a few years of his death, he was quite regular in his attendance at the monthly meetings, and a frequent participator in the discussions and debates, and his interest in the INSTITUTE was at all times manifested by his advocacy of every measure calculated to increase its usefulness and influence.

MR. MITCHELL was a man of pleasing and dignified presence, and was most affable and courteous in demeanor and in his intercourse with others. His private life was blameless, and those who knew him best will cherish his memory as that of a man animated by a nice sense of personal honor, and by the desire to be useful to his fellow-men.

EDWIN J. HOUSTON, ALEX. E. OUTERBRIDGE, JR.,

THEO. D. RAND,

CHAS. E. RONALDSON, WM. H. WAHL.

BOOK NOTICES.

SUR LA CONSTITUTION DE LA NAPHTALINE ET DE SES DÉRIVÉS. By F. Reverdin and E. Noelting. Reprinted from the *Bulletin de la Société Industrielle de Mulhouse*. pp. 76, with twenty extensive tables. 8vo, paper, 6 marks. Mulhouse, Alsace: Veuve Bader et Cie.

In drawing the attention of American chemists to this valuable work, a better idea of its aim and scope could not be conveyed than that contained in the first two or three of its opening pages. "Among the hydrocarbons which have attracted the attention of chemists, from a theoretical as well as from a practical point of view, naphthalene occupies certainly a place in the foremost rank. Its substitution products offer numerous cases of isomerism, and under each category the influence of the position of the substituting atoms and atom-groups upon the properties of the compound may be studied in a great number of examples.

"Moreover, within the last twelve years, the derivatives of naphthalene have, in an industrial point of view, assumed an enormous importance.

"In the first phase of the development of the industry of the artificial coloring matters, from the discovery of mauveine, of fuchsine and its derivatives, up to the discovery of artificial alizarine, the primary substances were furnished exclusively by the hydrocarbons of the benzene series. Attempts

had also been made, indeed, to prepare coloring matters by applying to naphthylamine and naphthol those reactions which, with aniline and phenol, had furnished such varied and beautiful bodies, and in certain cases products with tinctorial properties had been obtained, but save binitronaphthol, none of them were ever employed on the large scale.

"In 1869, the synthesis of alizarine attracted attention to a hydrocarbon up to that time almost unknown, anthracene, and made it the starting point of a magnificent industry. It was not until 1874 that naphthalene, in consequence of the discovery of eosine, made its entrance into the domain of chemical industry; serving, as is well known, for the preparation of phthalic anhydride, one of the primary substances employed in the formation of this dye.

"Its consummation in point of importance was not reached, however, until in 1876–1877, the industry of the azo-dyes underwent an unexpected and enormous extension.

"A great number, one can in fact say, the majority of the azo-dyes are derivatives of the naphthylamines, of the naphthols, or of the sulphonic acids of the same.

"The development of the industry of the azo-derivatives of naphthol has become a new demonstration of the importance of the study of isomerism of position, for the practical chemist; while no where else perhaps can one better prove the effect of this isomerism on the tinctorial properties of the bodies. Indeed, not only the colored derivatives of α- and of β-naphthylamine, of α- and of β-naphthol are capable of being sharply distinguished, the one class from the other, but even the isomeric sulphuric acids of one and the same naphthylamine or naphthol give from point of view of their application very unlike results.

"Thus, to cite only a few examples: The compound resulting from the combination of diazophenylsulphonic acid with α-naphthol is a brown, with β-naphthol it is a beautiful and brilliant orange; β-naphthol under the influence of concentrated sulphuric acid furnishes two bi-sulphonic acids, which when coupled with diazoxylol, the one gives a yellow ponceau, while the other gives a bluish ponceau; from the same β-naphthol two monsulphonic acids are also derived, producing by combination with diazotised amido-azo-benzol sulphonic acid the one a dull orange, the other a magnificent scarlet. Diazotised toluidine produces, according to the naphthalene derivative with which it is combined, reds, violets and even blues.

"We see from these few facts how the exact knowledge of the isomerism in the naphthalene series can become interesting from a practical standpoint. This knowledge is none the less interesting viewed from the theoretical side. While the benzol series presents only examples of quinones and nitroso derivatives of the para-series, naphthalene affords us the opportunity of studying as well the properties of like derivatives of the ortho-series; the study of ortho- or β-naphtho-quinone possessing a peculiar interest.

"The published researches upon the naphthalene derivatives are extremely numerous; they are scattered here and there through a great mass of chêmical literature, and it is not always easy to form a conclusion as to just how far such and such a class has been studied, and what is the number and constitution of its known representatives.

* * * * "The work which to-day we have the honor of presenting to you, and which shows the actual state of our knowledge of the naphthalene derivatives, is for the most part entirely new, having retained merely the general disposition of material peculiar to our earlier work.

"We shall discuss at the outset the constitution of naphthalene, the number of its isomeric derivatives and the methods for the determination of chemical position.

"Later on we give in the form of a series of tables all the known derivatives, indicating in few words the preparation, and giving the bibliography complete. With this arrangement, it will be easy for anyone who may wish to make a thorough study of certain categories of derivatives to refer directly without loss of time to the original memoirs. In many cases, from the preparation of a derivative, we are already in a position to draw conclusions relative to its constitution, while in other cases its transformation into a derivative of known constitution serves to establish the same. In many cases the structure has not yet been determined with perfect precision, or may even be altogether doubtful; when this is so, and in general where it appears to us advantageous, we shall discuss the formulæ in referatory notes annexed to each table."

Coming, as this work does, from the hands of those who not only occupy prominent places among the leaders in pure chemical research in Europe, but who, at the same time, from their eminent familiarity with the application of the results of this research in the chemical industry, are able also to speak with authority with reference to both sides of the subject, this book deserves to meet with a cordial reception amongst those who would advance our knowledge in this fruitful and fascinating field, as well as at the hands of those who are engaged with the industrial application of the principles of organic chemistry, to which latter class it cannot fail to prove a valuable aid.

A. G. P.

New Croton Aqueduct of New York. Report of the Aqueduct Commission, 1883 to 1887. 4to. New York City, January 1, 1887.

It rarely happens that the American engineer has either the time or money at his disposal for the preparation of elaborate monographs of extensive public works, and his experiences are therefore lost to the profession. In some cases the records are unearthed by foreign engineers and published in their technical journals, and thus the native engineer may learn something of the labors of his colleagues.

Hence it is that a publication such as that before us attracts so great attention, and is so eagerly sought after by the profession. To say that the report is complete gives but a feeble idea of its contents. The great value of the works consists not only in the statistics of precipitation, progress, cost, discharge, etc., but also in the graphical diagrams showing these data at every stage and condition of the work, and the beautiful phototype illustrations which so handsomely embellish the work and give it a practical value to the non-technical reader. The volume contains also complete working

drawings of the tunnels, shafts, syphons, reservoirs, dams, valves, gate-houses and other accessories, rendering it invaluable to a large class of constructors. L. M. H.

THE VOSBURG TUNNEL. By Leo Von Rosenberg, 35 Broadway, New York. 55 pp. 1887. 4to paper.

This is a special report upon a cut-off tunnel on the Lehigh Valley Railroad, in Wyoming County, Pa., whereby a bend of five miles is traversed by a double track tunnel of about 3,900 feet. The report is profusely illustrated, showing methods of conducting the work, progress, machinery, timbering, cost, dimensions, etc., and forms a very valuable contribution to the literature of the subject. L. M. H.

AMERICAN INVESTMENTS. Some Suggestions as to Causes of Existing Depression in Trade and their Remedy. Wm. L. Breyfogle, Louisville, Ky. 1886. *Courier Journal* Printing Company. pp. 36.

This brochure is important, not only for the information and recent data it contains, but as an able argument in favor of developing the resources of the South. The author remarks as to the latter: "It is, in truth, wonderfully rich in all the gifts of Nature, climate, soil, water-courses, water-power, timber, coal, iron, clay, stone—all the metals and minerals of common use to the world. It is within bounds to say that it has double the foundation of natural wealth on which to build an empire that the West had." After mentioning the business depression prevailing in the United States for several years up to 1885-86, and showing the great advantages the country possesses over Europe in its unity and not needing an expensive standing army or series of armies, the author says: "The North and South must now become either allies or rivals. If the first, both sections will gain unprecedented prosperity. If the last, then while the North must lose much, the South will gain something, but far less than if both sections move together. In other words, the South can grow in a way to build up the North, or it can grow at the expense of the North. Nothing can prevent its growth, but it is for the North alone to determine what share or part she will take in Southern development."

What follows are mainly proofs of this proposition, furnishing much valuable information and tabular data respecting the principal productions of the United States, and those of the South especially. This pamphlet has a historic as well as economic value, and the great advantage that the data are four years later than those of the tenth census. N.

SCIENTIFIC NOTES AND COMMENTS.

CHEMISTRY.

THE FORMATION OF ALLOYS (*Science*, **11**, 100).—William Hallock, of the United States Geological Survey, presented, at the meeting of the Philosophical Society of Washington, on February 18th, an interesting paper on the formation of alloys. In seeking an explanation of the results announced by W. Spring (*Berliner Berichte*, **15**, 595), who succeeded in obtaining certain alloys by subjecting a mixture of the constituent metals in fine filings to a pressure of 7,000 atmospheres, the author conceived the idea that if at any point the constituent metals were in contact, a minute globule of the alloy would be formed. If, during the compression, or subsequently, the temperature of the mass were raised to the fusing point of the alloy, this globule would melt and act as a solvent on the remaining mixture until the fusion of the whole mass. If this idea were correct, the same result could be obtained without pressure by giving more time and an appropriate temperature to the mixture of metals.

The filed metals required for Wood's alloy were mixed in the proper proportions and packed into a glass tube sealed at one end, no greater pressure being exerted than could be produced by a piece of one-eighth-inch wire held between the thumb and forefinger. The tube was suspended in a water bath at a temperature of 98–100° for eighteen hours, at the end of which time the filings had settled considerably. Tapping the tube on the table settled them still more, and in an hour the whole mass was fused. Tin and lead so treated melt at 200°, tin melting only at 230°. Sodium and potassium fuse to the liquid alloy at ordinary temperatures when clean-cut surfaces of the two metals are pressed together.

Thus "an alloy can be formed out of the constituents at a temperature above the melting point of the alloy, although it be far below that of any constituent, with no (appreciable) pressure." W. H. G.

"α" OXY-NAPHTOIC ACID AS A DISINFECTANT (*Pharm. Centralhalle, Dec. 8, 1887.*)—This acid, frequently referred to of late in periodical literature as a new compound, was discovered already twenty years ago by Eller, and the formula $C_{11}H_8O_3$, graphically expressed

$$C_{10}H_6\begin{cases}OH\\COOH,\end{cases}$$

correctly given by him. Eller proposed for it the name carbo-naphtolic acid, but did not separate that obtained from α-naphtol from that gotten from β-naphtol. This separation was shortly after effected by L. Schaeffer (*Ann. der Chem. and Pharm.*, **152**, 291. 1869). He found that the α-acid gave a blue color with ferric chloride, while the β-acid gave a violet-black inky color.

The α-acid fuses at 185° C. The β-acid, obtained with greater difficulty, and fusing at 235° C., was studied more fully by Battershall (*Ibid*, **168**, 121) in 1873, whose results were confirmed by Strumpf (*Ibid*, **188**, 4) in 1877.

Of the innumerable naphtol derivatives obtained since that time, these acids have specially excited practical interest because of their strong antiseptic properties. The firm of "Heyden, successors," obtained a German patent (No. 38,002) on the 8th of July, 1886, for the use of carbon dioxide under pressure, at a temperature of 120° to 140° C., upon the alkali salts of α- and β-naphtol. The discoverer of this process (so similar to the salicylic acid process) was R. Schmitt, who, with Burkard (*Ber. der deutsch. chem. Ges.*, 20, p. 2699), described a whole series of derivatives of these carbonaphtoic acids.

On account of its greater stability, the α-acid has hitheito been alone considered, and this, by the new method, can be made very cheaply (the kilo costing, at wholesale, according to purity, from six to ten marks, or $1.44 to $2.40). It forms needle-like colorless crystals, which are difficultly soluble (1 to 30,000) in pure cold water. The odor resembles that of naphtol, and excites sneezing. When carefully heated, the acid sublimes unchanged. As before mentioned, the solution is turned blue by ferric chloride, but with a shade of green. If the acid is pure, the solution keeps unchanged; the commercial acid, however, changes in sunlight, first to a yellow and then red. At a boiling temperature, naphtol is formed in the solution, while carbon dioxide is liberated. The ethereal, alcoholic and other solutions as yet need not be practically considered, nor any of the salts which are prepared with difficulty and are mostly only slightly characteristic. The crude acid contains 0·4 per cent. of ash, consisting of lime, iron, alumina, chlorine, sulphuric acid, etc. The antizymotic action of α-naphtoic acid, according to a statement of Holmes (*Pharmaceutical Journal*, thirty-second year, p. 662, November 19th, 1887), is five times stronger than that of salicylic acid. Though we may hesitate to express such differences of effective strength by definite numbers, we may readily convince ourselves of the greater power of the new disinfectant by making an experiment with blood. If, for example, we add a few decigrams of salicylic acid to fifty centimetres fresh bullock's blood, putrid decomposition is not materially arrested, while with an equal addition of α-oxynaphtoic acid, the odor of putrefaction will not develop for weeks. Still more striking is the antiseptic action when urine is taken.

This property of the acid, in connection with the fact that it can be manufactured so cheaply, has attracted the attention of students of hygiene and veterinary surgeons. The publication of a series of experiments concerning its physiological and germicide qualities, by Lübbert and several veterinary institutes, is shortly expected to appear in the technical journals. Unfortunately the general use of the substance is rendered more difficult on account of its slight solubility in water. Likewise its use in preserving articles of food will be precluded by its poisonous character. On the other hand, its poisonous effects will not hinder its use as an antiseptic in surgery in the light of the experience gained with corrosive sublimate.

It will, perhaps, replace iodoform, which has lately been called into question, its solubility in ether making it possible to obtain a stable half per cent. collodion solution.

The α-oxynaphthoic acid will have possibilities in the following cases: To keep paste and similar materials odorless, to disinfect water closets, etc., in

fact in all instances where powder-like disinfectants may be used, and lastly in cases where sublimate is excluded on account of the presence of albumenoid matter. S. P. S.

A NEW SOURCE OF GERMANIUM.—Gerhard Kruss (*Berl. Ber.*, **21**, 131) has found germanium in the acid residues from the treatment of euxenite, and by working up a kilogramme of the residue obtained by extraction of euxenite with potassium acid sulphate, he was able to identify the element beyond doubt by the preparation of its sulphide, oxide and chloride, besides the isolation of the metal itself, comparison being made directly with the oxide of germanium prepared by Winckler and furnished by him. The discovery is of little more than theoretical interest at present, for the proportion of germanium in euxenite does not exceed one-tenth per cent. It seems probable that the element may be found in other titaniferous minerals, and experiments for its discovery are to be undertaken on rutiles, yttrotitanites, wöhlerites, etc. W. H. G.

ON THE REGULAR GENERATION OF GASEOUS HYDROGEN PHOSPHIDE.—J. Messinger and C. Engels (*Berl. Ber.*, **21**, 326) have found that phosphine is produced regularly and easily by the action of aqueous ether on phosphonium iodide. The ether of commerce contains sufficient water, and the operation is conducted satisfactorily in a small Kipp's apparatus; five grammes of phosphonium iodide will produce a current of the gas for an hour. The hydriodic acid formed at the same time is entirely retained by the ether, forming a layer which is insoluble in the latter liquid, and collects at the bottom of the apparatus. W. H. G.

THIOCARBONYL CHLORIDE (*Berl. Ber.*, **21**, 337).—This compound $CS\,Cl^2$, formerly difficult to prepare, may now be obtained in quantity in commerce, being manufactured for technical purposes. Henry Bergreen has examined the commercial product and describes that sent out by Kern and Sandoz, of Basle, as a red, mobile liquid, slowly decomposed by atmospheric moisture, and fusing in the air. Its odor is penetrating, attacking the mucous membranes and producing a sensation of sweetness. It boils between 68° and 74° C. It contains a proportion of carbon tetrachloride from which it is scarcely possible to separate it by distillation. W. H. G.

HYDROQUINONE AS A DEVELOPING AGENT for gelatine plates has passed the experimental stage, and it remains only to cheapen it to insure a large demand. The advantages it presents over pyrogallol, especially to amateurs, appear to be in the simplicity of the developer, its keeping qualities, and the possibility of continuous use of the same solution for weeks, whilst the quality of the negatives is claimed by some to be superior to those by pyrogallol in some respects. The following formula is given by Dr. Piffard:

Hydroquinone (Merck's),	100 grains.
Carbonate of potash,	300 grains.
Sulphite of soda (crystals),	400 grains.
Water,	20 ounces.

Mix and filter, and, after use, return to the bottle for future use. It is adapted to varied exposures from flash light to time exposures. A weaker developer is highly recommended by Mr. Carbutt for lantern slides, and for

making intense negatives from black and white drawings for photo-mechanical processes, on account of the clearness of the shadows with great density of the high lights obtainable by it. The tone of the transparencies is also said to be very agreeable, and the quality from a thin or over-exposed negative better than can be obtained with ferrous oxalate.

As a still further simplification, M. Balagny recommended very highly to the Photographic Society of France, the immersion of exposed plates, whatever the nature of the subject, in a vessel containing a large quantity of developer and removing as they may be developed. The developer recommended, consisted of 100 parts of a twenty-five per cent. solution of sulphite of soda, 200 parts of a twenty-five per cent. solution of carbonate of soda, and twenty parts of a ten per cent. alcoholic solution of hydroquinone. C. F. H.

EXPLOSION OF ETHER LIME-LIGHT APPARATUS.—The British *Journal of Photography*, March 2, 1888, gives an account of the explosion of an ether saturator while in use with a pair of dissolving lanterns. The lanterns were overthrown, operators bruised, and flaming ether was thrown about the room, burning furniture, etc. The saturator was in the form of a tank containing liquid ether, over the surface of which the oxygen was made to pass by a circuitous route. Other serious accidents have resulted from the use of this form of ether saturator, and the dangers of its use have been repeatedly pointed out and warned against. The fatal defects of this saturator are: first, that the passage for oxygen is so very large (growing larger with the consumption of the ether) that if, from any cause (such as the too rapid vaporization of ether in a cold room) the mixture becomes explosive, its bulk is sufficient to produce a violent explosion; second, that no matter how little ether there may be in the tank, it is sure to be thrown flaming about the room if such an explosion does occur.

The continued use of this dangerous piece of apparatus seems all the more surprising in view of the fact that an equally efficient and absolutely safe saturator has been on the market for several years, which is used in this country to the exclusion of every other form, and is fully endorsed by experienced lantern operators and men of science who have used it.*

In the Ives' saturator, the passage for oxygen is very small, and remains of the same size at all times, so that it is impossible to produce an explosion that will either burst or injure the saturator; and when the ether supply is low enough to permit of the production of an explosive mixture, it is impossible to throw any of it out by an explosion. Even this harmless explosion cannot occur so long as operators follow published instructions. F. E. IVES.

FORMATION OF SUGARS FROM FORMALDEHYDE (*Berl. Ber.*, **21**, 270).—O. Loew has obtained sugar-like substances by boiling solutions of formaldehyde with lead, iron and tin, lead acetate and certain organic substances. The substances appear to be of the nature of formose; their hydrazine compounds have about the same fusing points as those obtained from formose, and yield analytical results showing a corresponding composition.

W. H. G.

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* For a description of this apparatus, see this JOURNAL (**125**, 28, January, 1888).—W.

Making Copper Tubes by Electro-Deposition.—*Modern Light and Heat*, **4**, 324, gives us the following description of an interesting method of obtaining copper tubes by an electrolytic process, which has recently been devised by Mr. W. Elmore, of England. By this method tubes having a tensile strength of from fifty to 100 per cent. in excess of brazed tubes are easily made. The process is very simple and consists in depositing the copper on an iron cylinder which is constantly revolving in the bath at a fixed rate of speed. An agate burnisher, which moves slowly from end to end of the cylinder, much on the plan of the tool of a screw-cutting lathe, rubs down the fine crystals of copper, matting them together. When the deposit is sufficiently thick the cylinder is taken from the bath and subjected to the temperature of superheated steam, when the sudden expansion of the copper tube frees it from the iron core, and it can be removed. The breaking strength of such tubes is said to be from twenty-seven to forty-one tons per square inch. W.

A Delicate Test for Bismuth. E. B. Stone (*Jour. Soc. Chem. Industry*, **6**, 416).—When a dilute solution of bismuth sulphate, containing but little free sulphuric acid, is treated with a few drops of concentrated potassium iodide solution, a beautiful yellow color is produced, and is sensible with 0·00001 gramme bismuth oxide in ten cubic centimetres of solution. On account of the uncertainty which follows the similarity of the color to that which would be produced by the separation of a little iodine, Dr. Watson proposes that a little solution of lead nitrate be added to the neutral or only faintly acid liquid before adding the potassium iodide. The mixture of precipitated lead and bismuth iodides then has a color varying from orange to deep red. By careful operation, less than a millionth of bismuth in solution may thus be detected. W. H. G.

ENGINEERING.

Digest of a Report on Current Meter Observations, Mississippi River, near Burlington, Ia., 1879, by G. A. Marr. (Prepared by G. L. Martin, Department of Civil Engineering, University of Pennsylvania).

In 1878, Major F. U. Farquhar, U. S. E., was instructed to examine the Mississippi River above the mouth of the Illinois, for the purpose of forming a plan for the improvement of the low water navigation of this river and that of the Missouri. The portion of the river specially selected for study was between Burlington and Montrose. At the same time and place, a series of observations with current meters, with a specially constructed chronograph, was undertaken. The work was inaugurated by Major Farquhar, with Capt. B. D. Greene, U. S. E., in charge of the field observations for a portion of the time, but Mr. G. A. Marr, Assistant Engineer, "who submits the final report, was in immediate charge of the field work, and has prepared the tables and plates showing the results."

The apparatus used consisted of seven current meters and a chronograph, which was constructed under the direction of Major Farquhar. The chronograph was provided with eight pens working independently, so that six could

be used for current meters, giving an independent and complete record for each, while at the same time the two outside pens could be connected in one circuit for a time record by "being connected with a break circuit chronometer, and marking intervals of one second on each edge of the sheet." Instead of using a single meter and lowering it to different depths, six meters were used simultaneously as "on account of the great fluctuations in velocity, not only from the surface downward, but also in the whole volume of the water, it appeared that a system which would give simultaneous observations at several distinct points in a vertical plane would give much more reliable and valuable information than the use of a single meter at different depths."

For determining the current velocities, the current meters were held in "position at their various depths by a wire rope," the foot of which was held by a mushroom anchor weighing 150 pounds. The six meters used for the observations were placed at equal intervals from the surface to the bottom of the river.

RATING THE METERS.

The meters were frequently tested, and for this purpose a frame was prepared, which was held in a horizontal position and at right angles to the direction of the current. The meters were placed in the frame and carefully set at the same height. This gave a comparison of the meters at the same depth, and to eliminate errors due to lateral variations in the current, the meters were reversed on the frame. Arrangements were also made for comparing the velocities as determined by meters and by floats. In the greater number of the observations, the floats were tied at mid-depth. From a study of the results, it was found that the velocity was not uniform over different sections, and hence a comparison of the velocity of the float with that of the meter located just below the section could not be expected to give definite results.

From the chronographic sheets, which give a record for the whole six meters, the velocities for each minute is given and the curve plotted graphically. The depths and the observed velocities at these depths are taken as the co-ordinates and the curve drawn, from which the velocity at any point may be scaled. The mean average velocity of the water at the different depths of the same section of the river is obtained by averaging the mean vertical velocity curves for the different minutes. Thus, on October 7th, at the section having a depth of 19·5 feet, nineteen different minute velocities are obtained for each meter. The final curve is drawn from the means of these.

RATIO OF MID-DEPTH TO MEAN VELOCITY.

The special object in view in obtaining these results was to find the ratio between the velocity at mid-depth and the mean velocity. To do this, the velocity at mid-depth was taken from the plotted curve. The mean velocity was obtained from averaging the velocities at a large number of depths. For this purpose the results are taken from the mean vertical velocity curve for each 0·4 of a foot in depth. Humphreys and Abbot's formula, giving the ratio of mid-depth to mean velocity, is as follows:

$$V_m = V_{\frac{1}{2}d} - \tfrac{1}{12}(b\,v)^{\frac{1}{2}},$$

in which

$$b = \frac{1 \cdot 69}{(D + 1 \cdot 5)^{\frac{1}{2}}}$$

and V_m is the mean velocity, $V \frac{1}{2} d$ is the mid-depth velocity, D is the depth and "v the mean velocity of the whole cross section of the river." We now see what time and labor would be saved if a number could be determined which would express the ratio. In the equation, "v" is needed and it is difficult to obtain. In the present case it was found from "the mean velocities as determined on cross section I." These velocities were plotted and "from the plot the value of v could be taken very closely for any stage." The gaugings referred to were taken at the same time as the current meter observations. Thus, it is seen, the same opportunity for error offers itself in this case as in the other. The difference can be seen from an inspection of the annexed table, which is a small portion of one of the most important ones given in the report. To it has been added a column for the same day, so that a comparison might be made of the results derived from Humphreys and Abbot's formula and those obtained by using the coefficient. In both cases the mid-depth velocity used is the same, being that obtained from the current observations. There have also been added two columns not in the report. The first is the mean velocity taken from the plates for the depths corresponding to ·6 of the total depth, and the second shows the difference between the mean velocity and that obtained by taking ·6 of the depth.

INVESTIGATION AS TO RELATIVE ACCURACY OF DETERMINING MEAN VELOCITY BY A SINGLE OBSERVATION AT PROPER DEPTHS.

For obtaining the ratio of mean to mid-depth velocity, twenty-five results were obtained from the observations, giving a mean coefficient of ·958 with a probable error of ·029. If it were possible to obtain a ratio of the depth of mean velocity to the whole depth with but a slight probable error, it would again greatly simplify the work. From the present investigations, the probable error for the latter is greater than for the former, being ·071, the ratio of $\frac{D_m}{D}$, or of depth of mean velocity to total depth is ·622. Yet it might be possible to obtain sufficiently accurate results by taking the mean velocity as that found at a distance from the surface equal to ·6 of the total depth. For this purpose the two additional columns have been prepared. From an inspection of the twenty-five results it is found that the coefficient ·6 gives results in some cases closer to the true velocity than those given by ·958. The extremes are, for ·6, ·075 and for ·958, ·059. It will be seen, therefore, that a sufficiently accurate result for most purposes can be obtained by taking the mean velocity as that given by the meter when placed at a depth from the surface equal to ·6 of the total depth.

For the purpose of giving some definite knowledge concerning the question of velocities, the experiments were worthy of the trouble which Mr. Marr took to obtain the statements, but it is hardly possible to undertake such careful observations in every case. The circumstances and phenomena connected with the matter are so variable that the results can never be obtained with the desired degree of accuracy at any one point.

TABLE.—COMPILATION OF RESULTS FROM PLATES OF FINAL PLOTTED CURVES.

$V_{\frac{1}{2}d}$ = mid-depth velocity. V_m = mean velocity. m = depth of mean velocity.

Date.	Stage.	Depth (D).	$V_{\frac{1}{2}d}$	V_m	V_m derived from $V_{\frac{1}{2}d}$ H. & A. formula.	V_m derived from $\cdot958\ V_{\frac{1}{2}d}$	m.	$\frac{V_m}{V_{\frac{1}{2}d}}$	$\frac{m}{D}$	$V_m - \cdot958\ V_{\frac{1}{2}d}$.	$V_m - V_m$ from $\cdot6\ D$.	V_m from $\cdot6\ D$.
1879, Oct. 14.	0·89	13·2	2·625	2·521	2·533	2·515	8·02	0·960	0·608	+ 0·006	. . .	2·520
		13·2	2·633	2·559	2·561	2·522	7·80	0·987	0·599	0·037	0·014	2·545
		12·9	2·604	2·533	2·532	2·495	7·80	0·973	0·605	0·038	0·006	2·539
		13·0	2·629	2·568	2·557	2·519	7·50	0·977	0·577	0·049	0·020	2·548
		13·0	2·624	2·559	2·552	2·514	7·56	0·975	0·582	0·045	0·010	2·549
Mean of 25 observations, ...								0·958	0·622			

L. M. H.

THE SIMONDS ROLLING MACHINE.—Fitchburg, Mass. (*Boston Herald* of Friday, February 24, 1888.) This unique machine is said by mechanical experts to be "the grandest mechanical invention of the age," marking a "new era in the manufacture of iron and steel." It is briefly described as a machine in which two flat surfaces, acting vertically or horizontally, and moving in opposite directions, with adjustable dies fixed on them, roll in one motion a piece of metal of regular or irregular shape, and in almost any pattern desired.

The work is perfectly accurate and very rapidly done. It is as if one took a red-hot steel bar and inserted one end of it in the machine and by

one stroke obtained the desired form, say a perfect sphere, or a conical shot, a chain screw or a bolt with thread, head and all complete, a car axle or a tiny calk for lumbermen's shoes; spindles or taper pins. For a vast number of articles it supersedes the work of the lathe, trip-hammer, planer and other machines requiring much loss of time and waste of material, for instead of cutting it away, it produces the proper form and size by compression and thus increases the strength of the product.

The invention is the outcome of a discussion upon a method of manufacturing a bolt, in which Mr. Geo. F. Simonds used, for illustration, a pencil rolled between the palms of the hand, and this was the germ which has been developed into the wonderful machine now running at the Simonds Brothers & Co.'s works at Fitchburg, Mass. L. M. H.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, March 21, 1888.*]

HALL OF THE INSTITUTE, PHILADELPHIA, March 21, 1888.

Vice-President, W. P. TATHAM, in the Chair.

Present, 132 members and fifty-two visitors.

Accessions to membership since last meeting, two.

Mr. FRED. E. IVES read a description of his suggestions for taking color photographs, and exhibited a specimen picture with the lantern.

Mr. A. O. GRANGER gave an oral description of the incandescent gas burner, adapted for non-luminous gas of any description, invented by Auer v. Welsbach, and exhibited a number of the burners in operation.

Mr. MORRIS P. JANNEY, of Easton, described and exhibited the operation of an automatic "Electric Water-Level Indicator" for steam boilers.

The above communications have been referred for publication.

Dr. WM. H. GREENE exhibited and described (for Messrs. Jas. W. Queen & Co., Agts.) some improved forms of fine balances.

The Secretary's report embraced the description and exhibition of a self-winding clock, on behalf of Messrs. Breitinger & Kunz, of Philadelphia, and of a number of specimens of the new product called Vulcabeston, made by the Johns-Pratt Company, of Hartford, Conn.

The presiding officer announced in suitable terms the death of Prof. JAS. C. BOOTH, for many years an active member of the INSTITUTE and of its staff of instructors.

Mr. S. LLOYD WIEGAND followed with a eulogy of the deceased, in which he specially referred to his admirable qualities as a teacher. He moved that a committee be appointed to prepare an appropriate memorial for publication. The motion was carried.

The President appointed Messrs. S. Lloyd Wiegand (Chairman), Chas. M. Cresson, M. D., and Alex. E. Outerbridge, Jr., as the Committee.

Adjourned. WM. H. WAHL, *Secretary.*

FIG. 1.

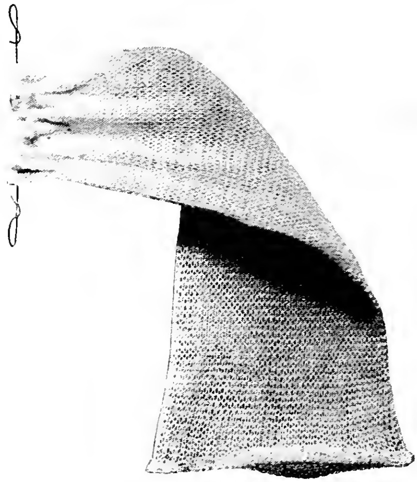

FIG. 3.

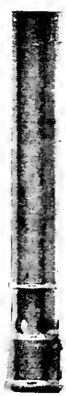

FIG. 2.

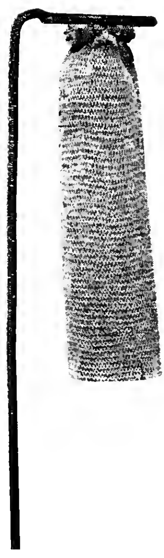

FIG. 4.

The Welsbach Incandescent Gas Burner.

// JOURNAL

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SOME RECENT ADVANCES IN PHOTOGRAPHY.

BY FRED. E. IVES.

The Lecturer was introduced by Prof. EDWIN J. HOUSTON, as follows:

It is unnecessary at the present stage of the world's progress to insist on the advantages of photography. We are fortunate in having with us this evening as a lecturer, on "Some Recent Advances in Photography," one who is himself a pioneer in this department of applied science. I allude to Mr. FREDERIC E. IVES, a distinguished inventor in the field of photo-mechanical engraving, by which the production of type-printing plates directly from nature is made possible, and who was the first to devise and employ a practical process for obtaining accurate monochrome photographs of objects in all colors, or, as these pictures are styled, isochromatic photographs.

Mr. IVES then spoke as follows:

There is so much to be said on the subject of recent advances in photography, that it would take several lectures to cover the ground fairly well; I have therefore engaged only to speak of *some* recent advances in photography, and shall devote most of my time to those branches with which I am most familiar.

The most important recent advances in photography are the rapid gelatine bromide dry plate process, the isochromatic or color-sensitive processes, film photography, and the platinum and bromide paper printing processes—all of which have come into use within ten years past. The same period has also witnessed great advances in the applications of photography to the printing press, including the first commercially successful production of type-printing plates direct from ordinary photographic negatives.

THE DRY PLATE PROCESS.

The modern rapid gelatine bromide dry plate differs from the old wet collodion plate in being from ten to 100 times more sensitive, and in keeping for years before exposure or development. The increase of sensitiveness is valuable for many purposes—especially for making photographs of rapidly-moving bodies and objects that are dimly lighted; their keeping qualities render them useful for a great variety of purposes for which wet collodion plates are unsuitable. Because of these advantages, the introduction of this process has very greatly extended the application of photography, which is now largely employed by scientists in the pursuit of their investigations, by artists to assist them in their labors, by travellers to secure souvenirs of their journeys, and by thousands of people of both sexes, young and old, in the pursuit of pleasure.

The first successful gelatine bromide dry plates were made by Dr. Maddox, an amateur photographer, in England, in 1871; and the first gelatine emulsion commercially produced was advertised for sale by Mr. Burgess, in 1873. These emulsions were not remarkably sensitive, although somewhat more so than wet collodion plates. It was not until 1878 that Mr. Bennett, another amateur photographer, discovered that an emulsion of extraordinary sensitiveness could be produced by prolonged digestion at 32° C. In that year many experimentalists produced plates that were prob-

ably equal in every respect to the best commercial dry plates of to-day.

It took several years to convince practical photographers generally of the superiority of the gelatine dry plate method, but it has now superseded the collodion process for nearly all purposes, and thousands of important photographs have been made by it that would never have been made by the older method. The list includes photographic maps of the heavens, photographs of star and solar spectra a hundred times more perfect than could be produced on wet collodion plates, photographs of lightning flashes, balloon photographs, photographs of animals in motion and birds on the wing, etc.

One of the most popular applications of this process by amateurs is in the production of instantaneous pictures, by daylight with the so-called detective camera, and at night by the magnesium flash light.

FILM PHOTOGRAPHY.

Film photography is a method of producing the rapid gelatine bromide process negatives on paper instead of glass. This method offers the important advantage that, as the support for the sensitive film is extremely light and flexible, it can be used from a roll, and a great many exposures made upon the contents of a single roll holder. After development, the film negatives can be stripped from the paper support, preserved between the leaves of books and printed from as well and as quickly as glass negatives. This method is most useful to travellers, but is not likely to be adopted to any extent for home work. Lantern slides have also been made on these films, and a hundred of them may be carried in a pocket without inconvenience.

THE GELATINE BROMIDE PRINTING PROCESS.

The gelatine bromide printing process is an application of the gelatine bromide process to the production of positive prints by development. Suitable paper is coated with the gelatine bromide emulsion, and the development of the picture is effected with ferrous oxalate. The extreme sensitiveness of this paper makes it the easiest method we have for producing large prints from small negatives. The prints have a neutral tone that is pleasing and artistic.

THE PLATINUM PRINTING PROCESS.

The platinum printing process gives about the same effects as the bromide paper process, and is cheaper, but can be employed only for contact printing, or with the solar camera.

ISOCHROMATIC PHOTOGRAPHY.

Next in importance to the rapid gelatine dry plate process, is the isochromatic, or color-sensitive process. Ordinary photographic sensitive plates are comparatively insensitive to the green, and still more so to the yellow and red of the spectrum, so that those colors photograph much too dark, while blue and violet photograph too light. By means of plates made sensitive to the green, yellow and red rays, and employed in conjunction with light filters of colored glass, this defect may be corrected. Many paintings and art objects that could not be photographed successfully in the ordinary way because of their colors, are now reproduced in a most satisfactory manner by this method, which is variously known as the isochromatic, orthochromatic, and color-sensitive, or correct-color-tone process. Bromide of silver is made sensitive to the green, yellow and red rays, by treatment with certain organic compounds, such as chlorophyl, cyanine, eosine, etc.

Dr. H. W. Vogel, of Berlin, was the first to discover that bromide of silver can be made sensitive to color in this manner. In the course of some experiments in spectrum photography, he observed that plates prepared by a certain process showed relatively more green sensitiveness than ordinary collodion bath plates, and at once set to work to discover the cause. It appeared that it might be due to the color of the film, which was reddish, and he tried the effect of dyeing the film, hoping that the light absorbed and held in the film by the dye would be forced to act upon the sensitive salt. It would be contrary to all known physical laws for the mere coloration of a sensitive film to produce this result, but Dr. Vogel found that certain dyes did, in some way, produce color-sensitiveness, and he went so far as to produce, in his laboratory, a photograph of a blue ribbon on a yellow background, in which the ribbon came out darker than the background. His effort to prove a false theory led to an important scientific discovery. His plates were not, however, sufficiently sensitive to color to have any com-

mercial value, having, indeed, far less absolute color sensitiveness than the ordinary uncolored rapid gelatine dry plate of to-day; nor was the sensitiveness distributed throughout the lower portion of the spectrum, as it must be, in order to permit of the photographing of all colors correctly at one time.

Becquerel and Waterhouse, who soon after confirmed Dr. Vogel's results, each discovered a new and better color-sensitizer. Becquerel, in 1875, announced that by means of chlorophyl he had made plates from one-tenth to one-fifth as sensitive to the deep red of the prismatic spectrum as to the violet. Waterhouse, in 1876, announced that he had obtained strong yellow-green sensitiveness with eosine; he also made photographs of colored objects on the eosine plates, but as he employed no light filter, the blue and violet rays still did nearly all the work, and he reported the experiment a failure. Ducos du Hauron, of Paris, made some use of both chlorophyl and eosine in experiments in heliochromy in 1876–77, but did not try to produce correct monochrome photographs of colors.

The first correct-color-tone photographs of objects in all colors were made by myself in the laboratory of Cornell University, in the summer of 1878. They were made with collodion bromide emulsion plates, sensitized with myrtle-chlorophyl and an infusion of tea, and exposed through a light yellow medium. These plates were from twenty-five to fifty times more red-sensitive than those of Becquerel, and had also relatively sufficient sensitiveness to all other colors. I published the method in 1879, but nobody tried it. Several years after, similar processes were announced in Europe, and, in 1886, the FRANKLIN INSTITUTE, after a careful investigation, endorsed my claim to priority. Measured by results only, this original process leaves nothing to be desired, except the colors themselves, and is not equalled by any other yet discovered. It is the *only* process that will photograph the deep red pigments successfully,—but it is a comparatively troublesome and delicate process to operate, and is successful only in a bright light, and with chlorophyl obtained from certain kinds of leaves. It is also impossible to keep chlorophyl without considerable loss of sensitiveness, and it has never been employed successfully with gelatine dry plates. After several years of experiment, erythrosine and cyanine have been generally adopted, because they can be successfully

employed with gelatine dry plates, which are far more convenient to use than collodion emulsion, and also more sensitive.

In order to show the characteristic action of the most remarkable color-sensitizers, I have made photographs of the prismatic solar spectrum on plates prepared as follows:

(1) Plain collodion bromide emulsion. Shows, with short exposure, no action in or below the green.

(2) Collodion emulsion, with erythrosine. Shows, with same exposure, enormous action in the yellow, a great deal in the green, and none whatever in the red. This is the most powerful yellow-sensitizer known.

(3) Collodion emulsion with cyanine. Shows, with same exposure, strong action in the orange-red and yellow, none in the green, and none in the deep red. This is the best red-sensitizer yet discovered for gelatine dry plates.

(4) Collodion emulsion, with year and a half old chlorophyl, which had been preserved by adding zinc powder to the alcoholic solution. Although the chlorophyl has lost two-thirds of its original sensitiveness to red and green, it is still superior to cyanine, both in extent and intensity of action, but has the disadvantage that it would have failed with a gelatine dry plate.*

Cyanine-erythrosine gelatine dry plates, although they do not compare at all favorably with chlorophyl collodion plates in *relative* color-sensitiveness, have greater *absolute* sensitiveness for all colors except deep red; and because of their greater general sensitiveness, easy preparation and keeping qualities, they have greater commercial value. The average photographer very much prefers good results by an easy process to better results by a more troublesome one.

It is also a lamentable fact that the number of photographers who have any scientific knowledge of this subject is exceedingly small, and much that is being said and published about it is either false or misleading.

In July, 1886, the Chairman of a London photographic society, who pretended to have tried the orthochromatic processes, said he had never seen a photograph in which blue came out darker

*Since delivering this lecture, I have discovered a simple and certain method of producing strongly color-sensitive gelatine bromide plates by means of chlorophyl. This method will be published soon.

than yellow. In December, of the same year, a well-known photographer said, at a meeting of the Photographic Society of Great Britain, that he believed orthochromatic photography to be a delusion; he added that he had not tried it, "nor did he intend to do so."*

Within three months past, a writer, having made some photographs on ordinary plates, exposed through a simple yellow color-screen, announced that "the orthochromatic processes" do not succeed in making red or orange photograph lighter than blue, but make the color defect somewhat less conspicuous! The author of "A History of Photography, written as a practical guide *and an introduction to its latest developments*," published within six months past, ignores the subject altogether. Others go to the opposite extreme, and speak of color-sensitive gelatine dry plates that "can be used without the color-screen," which is of course true, because *any* plate can be so used, but is, nevertheless, a very misleading statement when made in this connection.

The scientific and practical value of these methods has been sufficiently proved, and it is clear to me that the better they are known, the more extensive will be their employment for many purposes.

PHOTO-MECHANICAL ENGRAVING.

The earliest experimenters in photography recognized the desirability of a photographic method of producing type blocks from nature, and the subject received a great deal of earnest attention for a long time before any successful method was realized. The chief problem that had to be solved was the automatic translation of the graduated tints or shades of the photograph into pure line or stipple. A great variety of methods were tried, and a few good examples produced from time to time; but no mechanically accurate or reliable method was ever suggested previous to 1878. In August, of that year, Chas. Petit, of Paris, and myself, then at Cornell University, recognized, almost at the same moment, the principle upon which the first successful method was based. We did not, however, apply the principle in the same manner, and Petit's process was not commercially successful.

* On that occasion Mr. Thomas Bolas remarked, that "unless there was a grand conspiracy among eminent men in the scientific world to tell lies, there *was* something in orthochromatic photography."

THE IVES PROCESS.

The Ives process was introduced commercially in this city early in 1881. It has been described a great many times in book and magazine publications, and is now very well known. The invention is not, primarily, a plate-making process, but a process of producing, by purely photo-mechanical means, a substitute for the hand-made pen or crayon drawings formerly required in the production of printing blocks by the aid of photography. The first operation is the production of a photographic relief, by a simple, well-known method, with bichromatized gelatine. A film of bichromatized gelatine is first exposed to light under the ordinary photographic negative, then placed in water, where it swells up into relief, highest where the negative was most intense, and lowest where it was most transparent. A cast in plaster is then made from this wet gelatine relief; it has a perfectly white surface, but is high where a photographic print from the negative would be black, lower in the middle shades, and lowest in the whites. After the production of this relief cast, the process is purely mechanical and perfectly simple and scientific. An inked pad or film of elastic V-shaped lines or dots is pressed against the surface of the relief cast, until the lines or dots are completely flattened out where they meet the highest parts of the cast; when it is removed, there remains impressed upon the cast an ink picture having the appearance of an ordinary photograph, but made up of sharply defined lines and dots, which graduate in size like those of a wood engraving, and can be photo-engraved exactly like a pen or crayon drawing, or transferred to zinc or copper and etched into relief. I have some of the relief casts here, one of them bearing the ink stipple impression. The operation of producing the impression is, as you see, extremely simple, and the result is wonderful. The elastic lines of the printing pad being V-shaped, secure mechanically accurate graduation from deep shadows to extreme high lights, and the general effect can be greatly modified at will by changing the pattern of lines and dots. The best results are secured by the employment of a special elastic compound, and special ink, the composition of which has not been published.

Petit, whose original specification dates the same week as my own, blackened the surface of a white photographic relief, and cut in white lines, with a V-shaped tool, on a planing machine. Although

the principle is substantially the same, the processes are perfectly distinct, and Petit's was a practical failure.

For more than a year, the Ives process was the only one in successful commercial operation in the world. Its first rival was a method introduced by Meisenbach, in Munich, in the latter part of the year 1882.

THE MEISENBACH PROCESS.

In this method, the photographic relief is not required, and the definite negative is made, at one operation, from a photographic positive on glass, like the well-known window transparencies. In order to accomplish this, a glass plate, bearing a tint consisting of fine lines cut through an opaque film, is placed between the positive and the sensitive plate, to cut the picture up into lines. So far, there is nothing new in the method, and if it were not more than this, it would be utterly unscientific and practically worthless. To illustrate this fact, I have made a photograph of such a positive through such a ruled tint on a large scale, which I will show on the screen. It will be seen that the result is a mere skeleton of the picture; half of the detail is lost, and that which remains appears in lines that do not graduate in size, like those of a wood engraving, but only in color, like a photograph. It would be impossible to make a good printing plate from such a negative. It is essential that this interposer, technically known as a "grating," shall not only divide the picture into lines, but also cause those lines to graduate in size as well as in color, and that it shall do all this without completely obscuring any detail of the positive picture. There are several ways in which this can be accomplished in a strictly accurate, scientific manner, and one of these is suggested, though not fairly described, in Meisenbach's patent specification. He makes only two distinct claims, neither of which was sufficiently novel or specific to be allowed in the U. S. Patent Office. The first is merely a device for securing, with this method, the pattern of black cross lines in the shadows and white cross lines in the lights, which was already a recognized characteristic of the Ives process plates; the second is his means for securing the necessary graduation in the size of the lines. It is of interest to note that this last claim, which alone suggests the true inwardness of Meisenbach's method, has been generally omitted from printed descriptions of the process—probably because its significance was

not suspected. It consists of merely giving to the "grating" a very slight movement, at right angles to the direction of the lines during the exposure. This operation can be so conducted that the result will be as if each line of the "grating" graduated in color from centre to edge. Without taking the trouble to demonstrate the fact, I will state that in a negative made under these conditions, the lines will be graduated in size as well as in color, being thinnest where they are narrowest, and stronger at the centre than at the edges. It is possible to produce a "grating" that will give this result directly, without the movement, by molding in pigmented gelatine upon plate glass from a type metal plate ruled in V-shaped lines; the printing film employed in the Ives process becomes a most perfect "grating" of this character if soaked in a suitable solution of dyestuff and then dried. Another method, which requires no movement, is to employ a "grating" having very narrow transparent lines, place it at some distance from the positive picture, and use a lens diaphragm having a diamond-shaped aperture. There are still other methods equally as good or better. It will be seen that in each of these cases we have really another application of the V-shape principle that had already been recognized and applied in a very different manner by Petit and myself. But even with the most perfect means for graduating the lines, this method will not succeed if we attempt to make the definite negatives by a dry-plate process, because the lines, which should graduate in size only, will naturally also graduate in color. They can be made to approximate to the required character only by employing the collodion and silver-bath process for making the negatives, and taking care to keep the silver bath in a peculiar condition, which favors the development of a coarse-grained, intense, superficial image that intensifies readily up to the extreme edge of each dot or line.

A microscopic examination of negatives produced by the two methods I have described shows a very striking difference in the appearance of the lines; those in the Ives negative are perfectly sharp and smooth, while those in the Meisenbach negative are grainy and rough, especially in the parts that represent the shadows of the photograph. But this defect in the "grating" process does not prevent the production of good printing plates, and the Meisenbach process has been very successful in Europe,

where it has been operated under the personal supervision of Meisenbach himself. Its most marked defect is a tendency to produce muddy shadows, and considerable loss of color in the middle shades of the picture. The plates also require considerable fixing up, which is done very skilfully by burnishing, rouletting and re-etching. Considerable hand-work is also usually done upon the glass positive, to emphasize outlines, faint details, etc. The process itself is cheap enough to admit of the employment of skilled hand labor to help it out in this way, but many publishers decidedly prefer purely photo-mechanical work, which cannot distort outlines and change expressions.

There are new and better "grating" processes now in operation, perfectly distinct from that of Meisenbach, and combining some of the merits of each of the older methods, but they have not been published. Already these processes, none of which were in operation seven years ago, replace millions of dollars worth of wood engraving annually. In a single establishment in our own city, 3,000 of these plates were made during the past year, and hundreds of them have appeared in our illustrated magazines. I have prepared one frame of pictures to illustrate how perfectly these plates may be made to replace wood engravings. Eight pages have been taken from *Harper's Magazine*, four containing wood engravings and four Ives process plates of similar subjects. Three wood engravings are from artists' brush drawings, and three process plates are from similar drawings by the same artists. One wood engraving is from a photograph from nature, and one process plate is from a similar photograph made by the same photographer. The general effect is the same, and it is admitted by critics that the process plates, which only cost about one-third as much as the wood engravings, are quite equal to them in quality. The process plates here shown were finished without retouching of any kind—they are what we call "pure process work." But it must be confessed that many plates made by the same process are not as satisfactory as these, because the copy supplied, brush, drawing or photograph, is not so suitable for photo-copying.

There is one other kind of photography, which has never been successfully realized, but which I shall say something about, because I have to announce what I believe to be a definite and important step in advance. I refer to photography in colors.

HELIOCHROMY.

There are two distinct methods of making color photographs, in which the distribution of color is regulated by photographic action of the light itself. In one of these methods, the colors are produced directly by the action of light upon a peculiar silver compound; in the other, no colors are produced, but the action of light upon color-sensitive plates is made to regulate the distribution and combination of colors which constitute the final picture. Both of these methods have been made to produce pictures in which the blues, greens, yellows and reds of an object were represented in a general way by blues, greens, yellows and reds.

The first recorded observations on the photographing of colors by the first method, were made by Dr. Seebeck, of Jena, in 1810—twenty-nine years before the discovery of the Daguerreotype process. A brief translation that has been published, reads as follows: "When I directed the spectrum of a faultless prism (so placed that the incident angle of the front became equal to the refracting angle of the back) on white chloride of silver spread upon paper and still wet, through an opening of about five to six lines in the shutter, and to the distance where the yellow just meets with blue, and kept it by a proper arrangement in this position from fifteen to twenty minutes, I found that chloride of silver changed as follows: It had become red-brown in the violet (occasionally more violet, at other times more blue), and this coloration reached also beyond the line of the violet designated before, but was not deeper than in the violet. In the blue of the spectrum the chloride of silver became true blue, and this color decreasing and gradually getting lighter, extended into the green. In the yellow I found the chloride of silver mostly unchanged; sometimes it appeared to me more yellow than before; however, in the red, and often a little beyond the red, it had taken the red of a rose." Sir John Herschel, in August, 1839, alluding to results obtained in substantially the same manner, said: "The red is tolerably vivid, but is rather of a brick color than a pure prismatic red. The green is of a sombre metallic hue, the blue still more so, and rapidly passing into blackness. The yellow is deficient." Edmond Becquerel, in 1848, Neipce de St. Victor, in 1851, Poitevin, in 1865, and St. Florent, in 1873, made some advances upon this method, but the results obtained have never had any practical

value. The process is so insensitive as to require hours of exposure in order to secure camera pictures of objects illuminated by direct sunlight, and the colors obtained, which are neither correct nor sufficiently brilliant, cannot be fixed. The researches of M. Carey Lea, of this city, appear to have thrown some further light upon this subject, but have not yet helped to the production of any better results. Most people who are interested in this subject expect the problem to be solved by a method of this character; a few, including myself, do not.

Permanent and far more brilliant pictures have been made by the second method I have mentioned, which was originally suggested by Henry Collen, of England, in 1865, as follows:

"It occurred to me this morning that if substances were discovered sensitive only to the primary colors—that is, one substance to each color, it would be possible to obtain photographs with the tints as in nature by some such means as the following:

"Obtain a negative sensitive to the blue rays only; obtain a second negative sensitive to the red rays only; and a third sensitive to the yellow rays only.

"There will thus have been three plates obtained for printing in colors, and each plate having extracted all its own peculiar color from every part of the subject in which it has been combined with the other two colors, and being in a certain degree analogous to the tones used in chromo-lithography. Now it is evident that if a surface be prepared for a positive picture, sensitive to yellow rays only, and that the two negatives, sensitive only to blue and red, be superimposed either on the other, and be laid on this surface, the action of light will be to give all the yellow existing in the subject, and if this process be repeated on other surfaces sensitive only to red or blue, respectively, there will have been produced three pictures of a colored object, each of which contains a primitive color reflected from that object.

"Now, supposing the first great object achieved, viz., the discovery of substances or preparations, each having sensitiveness to each of the primary colors only, it will not be difficult to imagine that the negatives being received on the surface of a material quite transparent and extremely thin, and that being so obtained are used as above—*i. e.*, each pair of superimposed negatives to obtain the color of the third—that three positives will be obtained, each

representing a considerable portion of the form of the object, but only one primary of the decomposed color of it. Now, if these three positives be received on the same kind of material as that used for the negatives, and be then laid the one on the other, with true coincidence as to the form, and all laid upon a white surface, it will not be difficult to imagine that the effect would be, not only the representation of the form of the object, but that of its color also, in all its compounds.

* * * * * * *

"Although the idea I have endeavored to express in words may be utterly worthless, I am unwilling to let it slip away without notice, as it may, on the other hand, contain a germ which may grow and bear fruit in due season." *

Ducos du Hauron, of Paris, appears to have been the first to attempt to realize a practical process of this character. The theory of his method is substantially the same as that of Collen, but the details of his process were somewhat simplified. Instead of trying to produce plates sensitive only to simple colors, he proposed to employ plates sensitive to all colors, and to filter the light through suitable colored glasses, which amounts to the same thing. He also proposed to allow two colors to act upon each sensitive plate, instead of combining two negatives for the purpose of producing each pigment print; the result would be the same.

Now this method of Collen and Hauron is evidently based on Sir David Brewster's theory of the nature of light, which is, that there are only three primary colors, and that all the other colors and shades of color in the spectrum result from the combination of these in different proportions. It has been clearly established that this theory is false, and that the color of no part of the spectrum can be truly reproduced by the optical combination of other parts. On the other hand, it is true that the eye is readily deceived by

* Collen was Queen Victoria's teacher of drawing, and was not a photographer. His statement of his theory, if taken literally, is not perfectly consistent; he says "negative" when he means "sensitive plate," "sensitive to yellow" when he means "producing a yellow picture," etc., but he makes his meaning sufficiently clear when he adds, in one place, that he would employ "each pair of superimposed negatives to obtain the color of the third." If he had taken more time to formulate his theory, he would, doubtless, have stated it accurately.

such combinations, which may therefore be regarded as more or less successful counterfeits of the true colors. The painter who copies after nature does not attempt to secure green pigments that will analyze like chlorophyl in the spectroscope, but is satisfied to produce a color that appears the same to the eye, and readily does so. It is really possible to successfully *counterfeit* all the colors of the spectrum by means of three transparent solutions of seemingly pure color, separate and mixed in different proportions. A photographic method that would accomplish this selection and combination of type colors automatically, and in such a scientific manner as would invariably secure the representation of each distinct spectrum color by a definite and suitable color mixture, would, I believe, be the nearest approach to accurate photography in colors that we are likely ever to realize. Now it might appear, at first glance, that Hauron's process, although developed on a basis of false theory, would secure such a result. It will not. Although Hauron's description of his color-screens is not specific, from a scientific point of view, there is sufficient evidence that his process was, at best, merely calculated to divide the spectrum into three parts, each of which would be represented by one negative only, and by a single type color in the final result; a heliochrome of the spectrum itself, made in this way, would therefore be nothing more than three strips of even color, abruptly joined together at the edges, but combined in no other way. In practice, Hauron was very far from realizing even so much as this; a heliochrome of the spectrum itself, made by his latest and most approved process (1879), would be black where it should be red, reddish-black or brown where it should be orange, and red where it should be yellow. Albert, Bierstadt and others, who experimented with this method, obtained better results than Hauron, but all failed to realize a successful process.

This method, although it had to be abandoned as utterly unreliable, was found to reproduce many pigment colors very well indeed. This result was due to the fact that all bright pigments reflect the light of two or more parts of the spectrum, and in some cases, by mere coincidence, in such proportion as will secure for them approximately correct representation by a process that is incapable of producing a fair counterfeit of the spectrum. Inasmuch, however, as we do sometimes have to deal with nearly pure

colors, and the composition of the mixed colors is also infinitely varied, it is evident that a heliochromic process, in order to be successful, must be capable of counterfeiting the spectrum itself.

Such a process I have devised, and will now undertake to describe for the first time. As I have said, I reject the theory of three primary colors, recognizing the fact that the color of each part of the spectrum is perfectly distinct from that of every other part; I do not attempt the impossible feat of actually reproducing each ray of simple color, but I undertake to make each ray of simple color select, in a definite manner, and quite automatically, such a combination of type colors as will successfully counterfeit it to the eye.

Before proceeding to describe the process, I will illustrate the difference that may exist between true spectrum colors and very perfect counterfeits of the same. I will do this by analyzing various bright colors with a projection spectroscope. It will be seen that aniline yellow, which counterfeits the yellow of the spectrum, is really a perfect mixture of all colors except blue and violet. Aniline green, which counterfeits the dark green of the spectrum, is a mixture of green, blue and deep red. Aniline violet, which counterfeits the violet of the spectrum, is as much blue and red as violet. I could show you a great many other equally striking examples, but these are sufficient to illustrate my remarks.

In order that I may make the theory of my process clear in a few words, I will commence by giving a list of the requisites for carrying it out, as follows:

(1) Transparent colored solutions, which counterfeit three simple spectrum colors, and can be made to counterfeit all others by mixing in different proportions. I call these my "reproduction colors."

(2) Photographic plates sufficiently sensitive to all parts of the visible spectrum.

(3) Means for filtering out, in a strictly accurate manner, such colored rays, and in such quantity or proportion, as may be required.*

* Compound color-screens produced in the manner indicated in a communication published in this JOURNAL, **122**, 123.

(4) A camera that will produce three negatives simultaneously, of exactly the same size, and from the same (or very nearly the same) point of view.

(5) Means for producing, from the three negatives, pictures colored by the three solutions described above, and means for combining the three colored pictures.

All of these things I have; but to go into the details of their production would occupy too much time. My process, then, to be brief, consists of making three negatives, on color-sensitive plates, which are exposed simultaneously in a triple camera, behind light filters that are carefully adjusted to transmit to each plate just the kinds and amount of light that will cause the resulting negative to make a colored picture, which, when combined with the other two colored pictures produced in the same manner, will counterfeit the colors of the spectrum, or the colors and light and shade of any object. In order to accomplish this, each spectrum color that is not counterfeited by any one reproduction color, must, of course, be represented by two negatives, in such a manner as will secure a definite and suitable combination of two reproduction colors in the final result.

I believe I have made my meaning clear, but will try to illustrate by reference to a diagram of the spectrum.

	Red.	Orange.	Yellow.	Green.	Blue.	Violet.
Spectrum colors,	A		B		C	
Reproduction colors,	1		2		3	
Negatives,	*1*		*2*		*3*	

If my reproduction colors *1*, *2* and *3* counterfeit the spectrum at *A*, *B* and *C*, the spectrum at *A* must be represented exclusively in negative *No. 1*, the spectrum at *B* exclusively in negative *No. 2*, and the spectrum at *C* exclusively in negative *No. 3*. Orange, occupying a position in the spectrum midway between *A* and *B*, is counterfeited by an equal mixture of reproduction colors *1* and *2*, and must therefore be equally represented in negatives *1* and *2*; in the same way, green in negatives *2* and *3*, and violet in negatives *3* and *1* (you will observe that I propose to counterfeit violet by a mixture of blue and red). Orange-red must be represented

in negatives *1* and *2*, but chiefly in *1*; orange-yellow in the same negatives, but chiefly in *2*, and so on.

All this can be accomplished in a most satisfactory manner, by the employment of special compound color-screens, which are adjusted by experiment upon the spectrum itself, in the manner originally suggested by me in a communication to the FRANKLIN INSTITUTE, in June, 1886. It is true the amount of labor involved in the adjustment of these color-screens is something enormous, but when it is done, it is done for all time.

The pictures may either be made in pigmented gelatine like Hauron's, or ordinary lantern slides from the negatives may be projected by means of a triple optical lantern and light of three colors. In the former method, the process is complicated by the fact that the pigment prints must in each case be of a color complementary to that of the mixture of color which produced the negative; in the latter method, each negative is represented by the reproduction color counterfeiting that which has been most active in its production. The latter method is the one I shall employ in demonstrating the process to you.

Although I have gone far enough into this subject to convince you that such a process must be a difficult one to reduce to successful practical operation, I have not yet spoken of one of the most serious difficulties that has been encountered; I refer to the difficulty of producing sets of negatives which bear a certain essential relation to each other in the matter of exposure, development and intensity. No matter how perfectly we may reproduce bright colors spread out on flat surfaces, the process will fail when we come to deal with the light and shade of objects in relief, if any one of the negatives or positive prints is relatively over or under-exposed, or over or under-developed, or too intense, or too thin. In such a case, a yellow which reproduced perfectly in the light shades of the picture, might appear orange, green or slate-colored in the shadows, or *vice versa*, and other colors would be equally imperfect. I find it necessary to prepare the three sensitive plates at the same time, with the same emulsion, and to develop them in the same developing solution, for the same length of time. Even with this precaution, the results are not perfect unless the sensitive plates are of a certain character, giving harmonious graduation from extreme high light to deepest shadow.

Evidently a process may be perfectly correct in principle and yet depend for its success upon conditions so difficult to attain that it will fail in practice. I believe that this process, although essentially difficult, may nevertheless be so perfected that it will not only counterfeit all the colors of Nature, but be practical and reliable in the hands of specialists who are properly instructed and equipped to operate it. If so, it will have very great value, even if applied only in the manner I shall show you to-night, and for a single purpose, which will suggest itself.

"The proof of the pudding is the eating." I have not yet proved the value of this process. Although I commenced work on it nearly eleven years ago, I have made only half a dozen full regular sets of negatives, and most of those were destroyed by fire at 715 Arch Street two years ago. My recent experiments have been devoted to perfecting certain details only. The single example that I shall show you to-night is my first and only attempt at a landscape, made more than six years ago, with comparatively crude apparatus and imperfect adjustment of color-screens. It is, however, a very remarkable picture, with colors scarcely less brilliant than they would appear on the ground glass of a camera, and substantially correct to the eye in every shade and detail.

I hope some time to be able to show hundreds of such pictures, all better than this one.

This illustration suggests one of the easiest and most profitable of the many possible applications of the method, viz., the illustration of popular lectures on travel, like those of Stoddard or Wilson. I feel sure the time is not far distant when that much, at least, will be successfully accomplished.

RUSSIAN AND AMERICAN PETROLEUM.

By Samuel P. Sadtler, Ph.D.

[*A Lecture delivered before the* Franklin Institute, *November 21, 1887.*]

American petroleum, or, more exactly, Pennsylvania petroleum, has, I am aware, been taken as a subject for lecture before this institution on several occasions already, notably in recent years by Mr. Chas. A. Ashburner, of the Second Geological Survey of Pennsylvania, and its geology and conditions of production as well as its refining and varied utilizations have been ably described. I am not aware, however, that it has been discussed in comparison with that equally wonderful and more recent production, Russian petroleum. It is my purpose then to describe briefly the conditions of occurrence of these two most important natural products, to note the chemical differences between the two "crudes," the differences of treatment made necessary in consequence, the characters of the respective products, and lastly the present and prospective commercial values of these two gifts of Nature. In speaking of the American field I shall speak, of course, essentially of the Pennsylvania production, for although we have Canadian oil, West Virginia oil, California oil and, prospectively of still greater importance, Ohio oil, the great bulk of the crude oil which is refined for illuminating and lubricating purposes, comes from what is called the Pennsylvania field. The extent and distribution of this oil-producing area is seen on the map (*projected on the screen*), taken from Mr. Ashburner's paper on the oil regions of Pennsylvania and New York, read before the Halifax Meeting of the American Institute of Mining Engineers, in September, 1885. Since the issue of this map, however, a considerable development has taken place in the neighborhood of Washington, Pa., so that an additional district, centring about the town of Washington, would have to be added. The combined area shown on Carll and Ashburner's map, as underlaid by oil-producing sands, is 369 square miles, stretching southwesterly from Alleghany County, N. Y., to Beaver County, Pa., on the Ohio River, the development centring about Bradford, McKean County, Pa.

The geological character of the oil-bearing strata has been very thoroughly studied by Messrs. Carll and Ashburner, of the Pennsylvania Geological Survey, and Prof. Peckham in his census report on petroleum. Mr. Carll has in his several reports, made to the Geological Survey, very clearly defined and described not only the groups of producing sand rocks, beginning with the three Venango County sands, the earliest producing rocks, but the different geological horizons, such as, to begin with the lowest, the Smethport sand, the Bradford and Alleghany group of sand rocks, the Warren and Clarendon sands, the Venango group before referred to, producing in Venango, Butler and Clarion Counties, and the Smith's Ferry heavy oil rock of Beaver County.

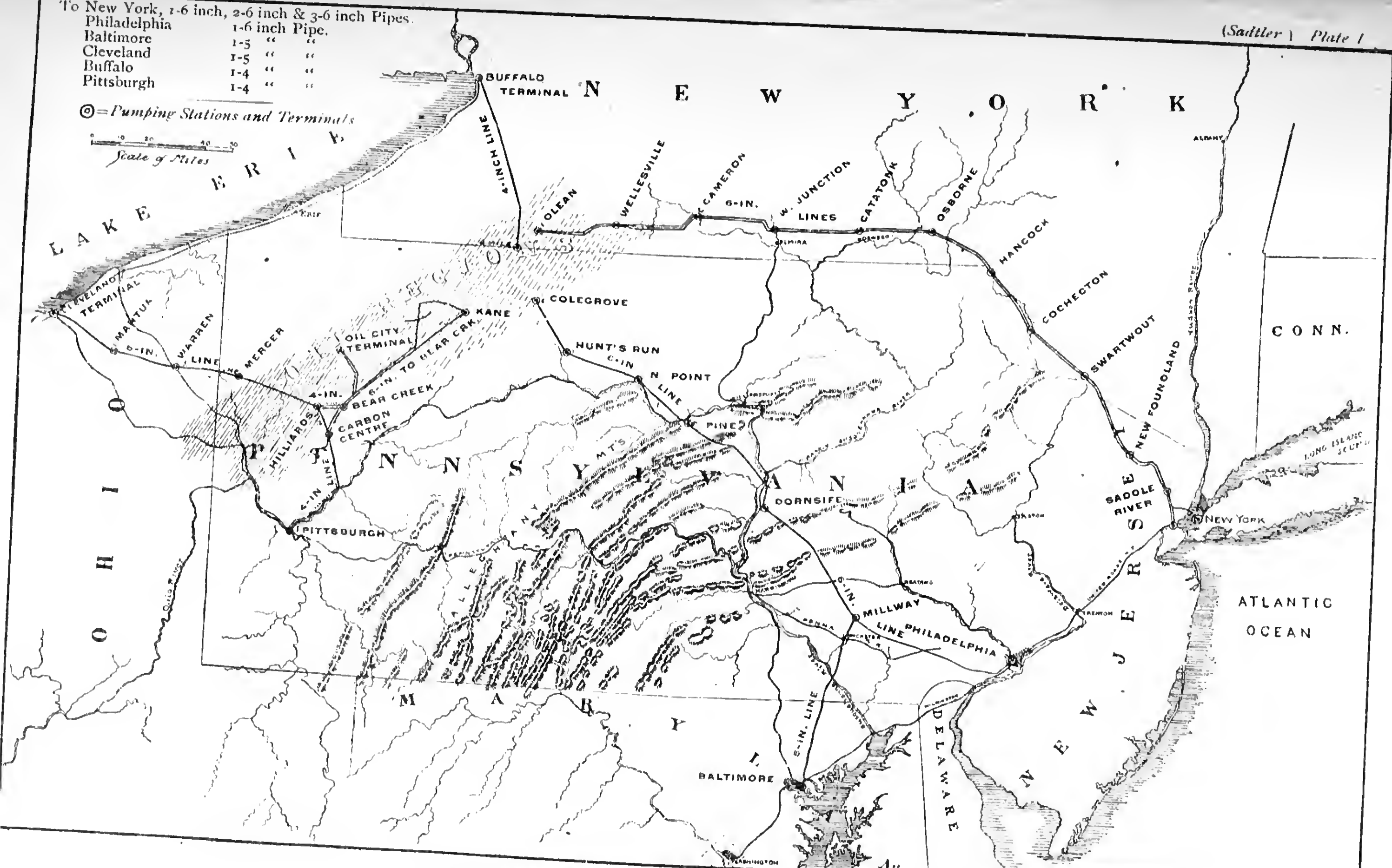
This sand rock of Western Pennsylvania varies in character from a coarse-grained uncemented sandstone, as in the Bradford district, to a pebble conglomerate of white or slightly colored opaque quartz, as in the Butler and Venango districts, overlaid by marls and slates, often highly silicated, forming very hard and impervious crusts. These formations, according to Prof. Peckham, "lie far beneath the influence of the superficial erosion, like sand bars in a flowing stream or detritus on a beach." "Taken as whole members of the geological series, the deposits lie conformably with the enclosing rocks and slope gently towards the southwest." The Bradford field, in particular, says Prof. Peckham, "resembles a sheet of coarse-grained sandstone, 100 square miles in extent, by from 20 to 80 feet deep, lying with its southwestern edge deepest and submerged in salt water, and its northeastern edge highest and filled with gas under an extremely high pressure."

While the oils found in this district may differ considerably in gravity, color, and undoubtedly somewhat in chemical composition, the differences are not fundamental, and with certain special exceptions, the crude oils from various localities are all brought together by the pipe lines and become mixed before going to the refineries. None of these Pennsylvania and New York oils contain any appreciable amount of sulphur or other impurity which would require a modification of the general refining methods. The heavy oils of Franklin and Smith's Ferry, Pa., and some few other localities, are so valuable for the manufacture of lubricating oils that they are collected and worked separately. The Pennsylvania crude oil has in general a dark greenish-black color, appearing claret-red by

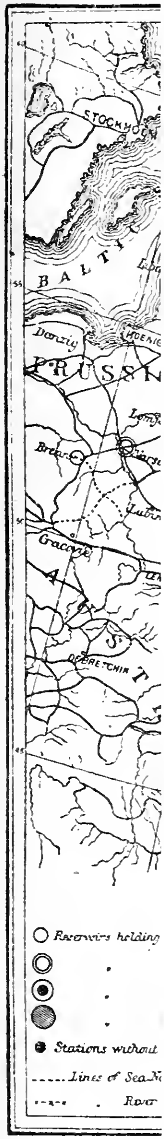
transmitted light, and varies ordinarily in specific gravity from 0·782 to 0·850, or as it is frequently expressed, from 49° B. to 34° B. Exceptions to this general statement are the Washington County amber oil, the light colored oil of Smith's Ferry and some other natural yellow or amber oils. In chemical composition it is essentially composed of hydrocarbons of the paraffin series $C_n H_{2n+2}$, the gaseous and the solid members of the series being alike held dissolved in the liquid ones and smaller amounts of the olefine series $C_n H_{2n}$ and the benzene series $C_n N_{2n-6}$. According to Markownikow, as confirmed by Krämer, Pennsylvania petroleum also contains hydrocarbons of a series $C_n H_{2n}$, which he terms "naphthenes."

The crude oil of the Pennsylvania field is mostly refined in the three large cities of Pittsburgh, Pa.; Cleveland, O., and Buffalo, N. Y., or on the Atlantic seaboard, in close proximity to the ports of shipment. The transportation of the crude oil to these points, at first effected exclusively by railway tank cars, is now very largely effected by means of pipe lines. Most of these are now controlled by the National Transit Company, and a map, showing their main pipe line connections, is here given. Their lines include a line from Olean, N.Y., to New York, Bayonne and Hunter's Point, 300 miles in length, and consisting of two six-inch pipes for the entire distance, and a third six-inch pipe for a portion of the way, with a transporting capacity of 28,000 barrels per day; a line from Colegrove, Pa., to Philadelphia, 280 miles in length, consisting of one six-inch pipe; a branch line connecting with this at Midway, Pa., and running to Baltimore, Md., seventy miles in length, consisting of one five-inch pipe; a line from Hilliards, Pa., to Cleveland, O., 100 miles in length, of five-inch pipe; a line from Four Mile, Cattaraugus County, N. Y., to Buffalo, N. Y., seventy miles in length, of four-inch pipe, and a line from Carbon Centre, Butler County, Pa., to Pittsburgh, Pa., sixty miles in length, of four-inch pipe. The New York line has eleven pumping stations, about twenty-eight miles apart; the Philadelphia line has six stations; the Baltimore line is one line without a break; the Cleveland line has four stations, and the Buffalo and Pittsburgh lines each two stations.

Still another trunk line is that of the Tidewater Pipe Company, which is a six-inch pipe extending from Rixford, in the Bradford



MAP SHOWNIG THE NATIONAL ...


STOCKHOLM
BALTIC
Danzig
PRUSSIA
Lomza
Brest
Lublin
Gracovie
DEBRETCHIN
Reservoirs holding
Stations without
Lines of Sea
River

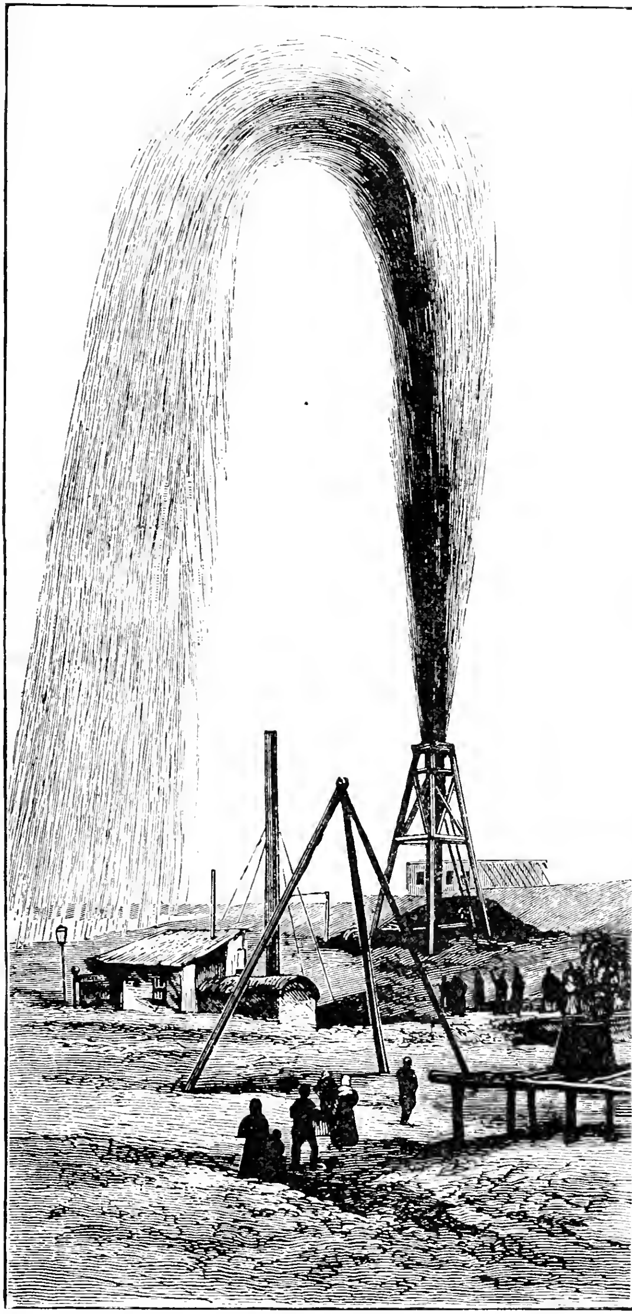
MAP SHOWING NOBEL BROTHERS' NETWORK OF PETROLEUM DEPÔTS IN RUSSIA.

field, to Tamanend, in Schuylkill County, where it connects with the Reading Railroad, by which the oil is transported to the seaboard in tank cars. The distance is 170 miles, and there are in this interval five pumping stations. The capacity of the line is 10,000 barrels per twenty-four hours.

If we turn now to the question of foreign petroleum production, we will find that only one locality deserves to be mentioned in comparison with our Pennsylvania production, viz: Baku, on the Caspian, in the Russian province of the Caucasus. The map (*projected on the screen*) will show the several known petroleum deposits of Europe and their geographical relation to each other, and to some extent the transportation facilities, as far as illustrated by the railway connections. The second or special map of the immediate Baku district will show the producing points and the refining centre on the outskirts of the town of Baku. As seen on this last map, there are two great groups of wells, the Surakhani and the Balakhani groups. The former exists on the site of the old fire worshippers' temple, where the petroleum gas has been issuing from the ground from the prehistoric period, 2,500 years ago, to the present. Only two or three companies carry on operations here. The majority are gathered at Balakhani, as a more copious supply was discovered here, and drilling operations were found to be more easily carried on.

The geology of this Baku district is not very definitely known. Vasilieff, in an article in the Russian *Mining Journal*, of September, 1886, states that the petroleum-bearing strata of the Caucasus belong to the Lower Miocene series of the Tertiary epoch, the deposits extending in a northeasterly to southwesterly direction, and the dip ranging apparently between 20° and 40°. The petroleum-bearing beds are composed of sand, calcareous clays, marls, and, in places, compact sandstones, often of great thickness, penetrated by bands of pyrites. The theory of Ludwig Nobel, based on numerous oil-well records made by his company, is that "the oil-bearing strata, originally running regularly in an almost diagonal direction, became dislocated and thrust hither and thither horizontally during some volcanic disturbance, and a sort of irregular cellular character given to the petroleum deposits." The peninsula of Apsheron is probably honeycombed with thousands of these oil cells, which seem to be for the greater part independent of each

other. They are found at all depths down to 825 feet, the extreme depth yet reached. The great Droobja oil fountain, which, in six months of 1883, poured forth about 55,000,000 gallons of oil, had reached a depth of 574 feet only, and while this was flowing at the rate of 2,000,000 gallons per diem, wells a stone's throw off and of lesser depth, were giving their daily supply of petroleum totally unaffected by it. Many of my audience have, perhaps, read newspaper items with regard to the terrific power and prolific character of some of these Baku oil wells, and may have put down much of the account to exaggeration. But numerous reliable and unbiased witnesses have united in giving figures that we must therefore accept. The largest flowing well we have had in Pennsylvania (the Armstrong No. 2) flowed for a time at the rate of over 6,000 barrels (or 260,000 gallons) per twenty-four hours. When Boverton Redwood, the Secretary of the British Petroleum Association, visited Baku in the fall of 1884, one of Nobel's capped fountains was opened for his benefit, and the sight then displayed is represented in the accompanying illustration. A solid column of oil, more than a foot in diameter, shot up to a height exceeding 100 feet, and continued to flow without diminution of violence as long as the valve remained open, forming a lake of oil to leeward of the well. The derrick was seventy feet high, and the oil column occasionally rose to at least double this height. This well (Nobel's No. 18) yields at the rate of 1,125,000 gallons per twenty-four hours whenever opened. It was, however, exceeded by the Droobja well before referred to, and Nobel's No. 9, each of which for a time having yielded double that quantity, or over 2,000,000 gallons per twenty-four hours, about eight times the amount yielded by the strongest Pennsylvania oil well known. The Nobel No. 9 was promptly capped, 1,000,000 gallons of oil being the total loss, but the Droobja well could not be gotten under control for over four months, and it is supposed that 100,000,000 gallons of oil were lost during this period. Not only this, however, but this Droobja fountain, which was from 200 to 300 feet high, threw out so much sand that neighboring engine houses and derricks were partly buried by it. The company owning it not only lost their oil, but were ruined by the damages they had to pay the surrounding well owners for flooding them with sand and oil. The maximum pressure previous to the discovery of these two fountains, had been



Oil Fountain. Baku Oil Region.

four atmospheres, but in the case of Nobel's No. 9 and the Droobja well the pressure exceeded thirteen atmospheres, or nearly 200 pounds pressure to the square inch. Of the 400 wells in the Baku district only about 100 are producing at present, and of these 100 some twenty are flowing wells. These twenty, however, would for a time yield more than enough crude oil to suffice for the manufacture of the 2,000,000 gallons of refined petroleum that the world consumes daily. Nobel Brothers had, moreover, at a recent date, fourteen oil fountains plugged up and held as a reserve.

Wells in the Baku district which do not flow, cannot be pumped in the ordinary way, in consequence of the large quantity of the sand present (sometimes as much as thirty to forty per cent.), and the oil is raised to the surface in cylinders resembling the sand pump. About two minutes are required to lower and lift the tubes, which bring about fifty gallons of oil to the surface each stroke. "Torpedoing" is so far unknown, as a well requires only to be bored a little deeper in order to bring fresh quantities of oil The oil on issuing from the well is always allowed to stand for a time in reservoirs (which are frequently only shallow ponds in the surrounding soil) in order to deposit the sand, and is then pumped through the pipe lines to the refineries at the Blacktown on the coast some eight miles off.

The Baku petroleum has a higher gravity than the American, averaging 0·873, or 31° B., and has been found to be entirely different in its chemical composition, consisting for the most part of hydrocarbons of the series C_nH_{2n}, isomeric with the olefine series and called "naphthenes." As will be seen later, this difference in chemical composition involves a difference in the refining methods and results.

The processes of distilling Pennsylvania petroleum are in a general way at least familiar to most of my audience, so I shall not take the time to go over them in detail. It is sufficient to say that although a normally conducted fractional distillation would give from thirty-five to fifty-five per cent. only of illuminating oil, by the process of "cracking," or destructive distillation, the percentage of illuminating oil may be increased to seventy-five to eighty per cent., the benzine fraction being from ten to fifteen and the residuum from five to ten per cent. On the other hand, the Russian petroleum does not yield over about twenty-seven to thirty

per cent. of illuminating oil of satisfactory quality, but will yield fifty per cent. of a very superior lubricating oil. Nobel Brothers, who are by far the most scientific and progressive in their methods, obtain about the following result: Benzine, 1 per cent.; gasoline, 3 per cent.; illuminating oil (32°C. or 89°F. Abel flash point), 27 per cent.; Soliarovi lubricating oil, sp. gr. 0·87, 12 per cent.; Veregenni lubricating oil, sp. gr. 0·89, 10 per cent.; lubricating oil, sp. gr. 0·905, 17 per cent.; cylinder lubricating oil, sp. gr. 0·915, 5 per cent.; vaseline, sp. gr. 0·925, 1 per cent.; liquid fuel, 14 per cent., and loss, 10 per cent; total, 100.

It is true that more illuminating oil than this twenty-seven per cent. is sometimes gotten by some of the Baku refiners, but it is of lower flash test. Prof. Beilstein, of St. Petersburg, has also proposed a method of cracking by which the yield of illuminating oil can be raised to fifty per cent., but it is not adopted as yet to any considerable extent. With regard to the character of the best Russian illuminating oil as compared with the best American oil, it is claimed by English and German experimenters that, while the Russian oil gives less light at the beginning of the burning when the lamp is full of oil and freshly trimmed, it affords a flame of somewhat greater permanence as the level of oil in the reservoir becomes lower, the difference being supposed to be due to the greater power which the Russian oil has of ascending the wick. In a comparison of the lubricating oils, there seems but little doubt that the Russian product has a distinct advantage. These lubricating oils from Baku petroleum contain little or no solid hydrocarbons, the greatest quantity obtainable amounting to only a quarter of one per cent. of the crude oil. They will show, therefore, exceptionally low cold tests. At the same time they have a remarkably high viscosity in relation to their specific gravity. This characteristic is exhibited in the following tabular statement, prepared by Boverton Redwood:

	Viscosity at 70° F.	Viscosity at 120° F.	Loss per cent. in Viscosity.
Russian oil (sp. gr. 0·913),	1400	166	88
American oil (sp. gr. 0·914),	231	66	71
Russian oil (sp. gr. 0·907),	649	135	79
American oil (sp. gr. 0·907),	171	58	66
Russian oil (sp. gr. 0·898),	173	56	67
American oil (sp. gr. 0·891),	81	40	50
Refined rape oil (for comparison),	321	112	65

It is true that the disproportion is chiefly at lower temperatures, the Russian oil losing its body relatively faster than the less viscous American oil. One distinctive feature of the Baku refining is the successful use they make of continuous distillation processes which are especially suited to Baku petroleums, as the quantity of burning oil separated being comparatively small the residuum is not very much less fluid than the crude oil. The stills, each of the capacity of 4,400 gallons, are arranged in groups or series of not more than twenty-five, and a stream of oil is kept continuously flowing through the entire number. The crude oil entering the first still parts with its most volatile constituents, passing into the next still has rather less volatile hydrocarbons distilled from it, and finally flows from the last still in the condition of residuum, which in Russia is termed *astatki*, or *masut*. The several stills are maintained at temperatures corresponding with the boiling points of the products to be volatilized. Superheated steam is used for all the stills, the steam being delivered partly under the oil and partly above the level of the oil; that is, in the vapor space above. The fuel used under all the stills in Baku is petroleum residuum, or "astatki." At many of the smaller works, the liquid fuel is simply allowed to flow upon the hearth of the furnace, and in thus using it, a very dense black smoke is evolved, whence the refining suburb of Baku has come to be known as the Blacktown. At Nobel's refinery, however, arrangements are adopted for burning the fuel with a proper admixture of air, and smokeless combustion is thus obtained. The part the astatki, or liquid fuel, now plays in the Caucasian district and in Russia is something not to be overlooked. It is the only fuel for locomotives, steamers and factory engines throughout this part of Russia. It has replaced wood and coal, and the use of it is now extending as far as Moscow to the north, Teheran to the south, Merv and Khiva to the east and Batoum to the west. In 1883, the aggregate export of astatki to Russia by all the Baku firms was 281,000 tons. On the other hand, the production was estimated as exceeding 500,000 tons, leaving, after making allowance for consumption in refineries, perhaps as much as 200,000 tons, or 50,000,000 gallons undisposed of. Enormous quantities are therefore allowed to go to waste. It is found in practice that with a good hydrocarbon furnace one ton of astatki goes as far as three tons of mineral fuel. Nobel Brothers alone are now turning out 450,000 tons of this fuel per year.

It remains now to glance at the methods of transportation and commercial development of Russian petroleum fields as compared with those of America. Our American system of pipe lines, extending to the seaboard, has already been illustrated. With the oil once at the Atlantic seaboard, its shipment either as crude or as refined is readily effected to any part of the habitable globe. Here, the Russians are at a disadvantage. Baku is on the Caspian Sea, on the border line between Europe and Asia, but with very imperfect means of communication. What there is may be said to have grown principally out of the wonderful energy and engineering ability of one man, Ludwig Nobel, a Swede by birth, although resident in Russia since his twelfth year. In 1875, his elder brother, Robert Nobel, began refining at Baku in a small way, with capital furnished by Ludwig, who had extensive engineering works at St. Petersburg. The Nobel Brothers found all the oil that was refined at Blacktown transported from Balakhani in barrels slung in two-wheeled Persian carts, termed "arbas." They laid down a pipe line eight miles long and paid its expenses the first season. They imported American oil-well borers and revolutionized the method of sinking wells. Then it was that, finding the transportation facilities too limited to allow them to ship their oil, Ludwig Nobel, the engineer, designed and had built the first of the oil-tank steamers that allowed him to ship his oil on the Caspian from Baku to the mouth of the Volga, a distance of 460 miles. This first liquid transport, or "cistern steamer," appeared on the Caspian in 1879. There is now a fleet of forty of them, the Nobel's owning twelve, carrying about 5,500 barrels apiece each trip. As the Volga at its wide mouth is very shallow, the tank steamers can proceed no farther than a locality termed "nine-feet sounding," about twenty miles from land, where the oil is transferred to oil barges, in which it is conveyed to Tsaritzin, the first railway point on the river Volga, 400 miles distant, where Nobel Brothers have established one of their great distributing centres for Russia. They have twenty barges on the Volga, and from Tsaritzin they distribute the oil by trains of oil-tank wagons. Of these, the Nobel's own 1,500, holding 2,600 gallons, or about ten tons of refined oil each. These are made up into trains of twenty-five wagons, so that the firm runs sixty such trains continuously in their distributing work. The accompanying map

shows the network of storage depots and distributing stations that the Nobel's have established throughout Russia and the adjacent countries. This system of storage depots is not merely a matter of convenience to them, but is to a large degree a matter of necessity. During at least four months in the year, the Volga is frozen over solidly, so that the oil needed for consumption during this winter term has to be accumulated at points accessible by rail connection. The oil trains of the Nobel's, therefore, are occupied during part of the year in collecting the oil in their storage depots, and during the winter in distributing it for consumption. This work is all directed from St. Petersburg, where Ludwig Nobel, the President of the company, resides. They are beginning also to ship their oil by tank steamers from Libau on the Baltic, where they bring it by tank cars, to Stettin, Hamburg and even to London. At Stettin, they have begun to erect storage tanks for the supply of the German trade.

In 1883, the Trans-Caucasian Railroad was finished, and oil is now shipped from Batoum on the Black Sea in quite considerable amounts to Mediterranean ports. A pipe line from Baku to Batoum has also been surveyed, and the Government concession having been obtained, it will likely be built in the near future.

The successful introduction of transportation of oil in bulk by means of oil-tank steamers on the Caspian, of course, led oil shippers to consider the question of using similar tank steamers for the transportation of American oil in bulk to Europe. Indeed, some slight experimenting in this line had preceded the adoption of the tank steamers on the Caspian, but the engineering difficulties connected with the shipment of oil in bulk for the voyage across the Atlantic were far greater, and hence greater precautions against danger had to be devised. Two large tank steamers, however, have been running this last year successfully, the *Crusader* and the *Andromeda*, the former to London and the latter to Bremen. The most important feature of their construction is the provision of auxiliary tanks above the level of the storage tanks and in communication with them. The storage tanks can thus always be kept quite full of oil, the auxiliary tanks serving to hold the surplus when the storage tanks become expanded by heat and supplying the deficiency when contraction takes place. The *Crusader* is provided with forty-five tanks, with an average capacity

of 125 barrels each, the *Andromeda* with seventy-two tanks, and carried in its first trip to Bremen 684,641 gallons of refined oil.

The statistics of production of both American and Russian oil and of exportations of the two, as far as statistics are attainable, are given in the tables in the Appendix.

I would, in conclusion, express my indebtedness for information on Russian petroleum matters to Boverton Redwood's lectures and articles in the *Journal of the Society of Chemical Industry*, to Dr. C. Engler's "Das Erdoel von Baku," reprinted from *Dingler's Polytechnisches Journal*, and especially to Chas. Marvin's work, "The Region of Eternal Fire," London, 1884. I am also indebted for personal favors to Mr. H. M. B. Bary, to Messrs. Fuller Brothers, and to the Atlantic Refining Company, of this city.

APPENDIX.

Table I.

Annual Production and Value of Petroleum in the United States, according to the Bureau of Mining Statistics, U. S. Department of the Interior.

	Production.		
1882,	30,053,500	barrels, valued at	$23,705,698
1883,	23,400,229	" "	25,740,252
1884,	24,089,758	" "	20,476,294
1885,	21,842,041	" "	19,193,694
1886,	28,110,115	" "	20,028,457

Table II.

Annual Production of Crude Oil in the Baku District, according to Engler.

1881,	4,900,000	hundred kilos, or	3,500,000	barrels.
1882,	6,800,000	" "	4,857,143	"
1883,	8,000,000	" "	5,714,286	"
1884,	11,300,000	" "	8,071,428	"
1885,	16,360,000	" "	11,685,714	"

Table III.

Exports of Crude and Refined Petroleum from the United States for the Years 1884–85 and '86, according to the U. S. Bureau of Statistics.

	1884.	*1885.*	*1886.*
Crude petroleum exported,	79,679,395 gallons.	81,435,609 gallons.	76,346,480 gallons.
Valued at,	$6,102,810	$6,040,685	$5,068,409
Naphthas and light distillates,	13,676,421 gallons.	14,739,469 gallons.	14,474,961 gallons.
Illuminating oils,	433,851,275 "	445,880,518 "	485,120 680 "
Lubricating oils,	11,985,219 "	12,978,955 "	13,948,367 "
Residuum and tar,	126,269 barrels.	136,474 barrels.	47,474 barrels.
Value of the refined products,	$43 354,396	$43 631,058	$43,076 795

Table IV.

The Shipments of Baku Petroleum for the Years 1885 and 1886 are thus given in the U. S. Consular Reports:

(1) From Batoum via Trans-Caucasian Railway—

	1885.	*1886.*
Illuminating oil,	26,865,325 gallons.	39,321,005 gallons.
Crude, lubricating and residuums,	4,774,600 "	14,915,315 "
Total,	31,639,925 "	54,236,320 "

(2) Via Astrachan on the Caspian Sea—

	First Six Months of 1886.
Illuminating oil,	44,428,335 gallons.
Crude, naphthas and residuums,	79,866,200 "
Other products,	8,851,960 "
Total,	133,146,495 "

ON SOME EARLY FORMS OF ELECTRIC FURNACES.

No. 6. NAPIER'S ELECTRIC FURNACE.

BY PROF. EDWIN J. HOUSTON.

Numerous suggestions have been made at early dates for utilizing the power of feeble electric currents in order to effect the reduction of various metallic ores. To accomplish this purpose the ores were dissolved by the action of suitable chemicals, and the electrolytic solutions thus obtained decomposed by the direct passage of the electric current.

In 1844, James Napier, of England, conceived the idea of preparing metallic ores, for the process of electric reduction, by heat in the place of chemical solution. This he accomplished by mixing the ores with certain fluxes and heating the mixtures to their point of fusion. The fused mass thus obtained was then subjected to the action of an electric current by the passage of which the reduction was effected.

The process suggested by Napier was a great advance over the purely chemical processes above referred to. Apart from the question of expense, the necessity for first obtaining a chemical solution of the ore to be treated, necessarily limited the class of reductions to which such a process is applicable. The comparative ease with which most ores can be reduced to the semi-fluid state by heating them in the presence of suitable fluxes is well known, and, where the electric resistance of such fluid masses is not great, the commercial practicability of the method proposed by Napier would appear to be assured.

Napier's process, it will be seen, is not unlike the method adopted at a much earlier date by Davy in his great discovery of the metals of the alkaline earths.

In carrying out his invention, Napier mixes the ores to be reduced with the fluxes and places the mixtures in crucibles of refractory materials, such, for example, as plumbago. These crucibles are covered on the inside with clay, except at the bottom, which is left uncovered. By this means the electric current is caused to traverse the molten mass from the surface to the bottom of the crucible.

The positive electrode of the decomposing battery is attached to an iron disc placed on the surface of the molten mass, while the negative electrode is connected with the outside of the crucible. Coke is sometimes used in place of the iron disc for this purpose.

Napier patented his furnace in England in 1844. His patent is numbered 10,362 of 1844, and is for "Improvements in treating mineral waters to obtain products therefrom, and for separating metals from other matters." Napier also took out letters-patent in Great Britain, No. 10,684 of 1845, for the same invention, the specification of which is the same as in the preceding patent. This latter patent covered the British colonies and other territory not protected by his former patent.

The following description is taken from the specifications of the preceding patents.

"The second part of my invention has for its object the application to metallic ores when in a fused state of a current of electricity, so as to separate therefrom the metals which they contain.

"I will proceed to describe the method which I employ in the treatment of copper ores, though the invention is applicable to ores of other metals which are capable of being held in fusion with fluxes. I take a large crucible, or other convenient vessel, made of an electro-conducting material, those I have used being of plumbago (common black lead). The inside of this vessel I line all around with a lute of clay, except the bottom, which I leave uncovered. The luting should be very thin and laid on in two or three coats, drying slowly between each, so as to prevent cracking. When the vessel is sufficiently luted and dried I put therein (with the usual fluxes) the regulus or calcined ore, which, when sulphurets are used, should have been well roasted so as to drive off as much as possible of the sulphur. I then place the vessel with its contents in an ordinary air furnace, keeping up the heat until the mass is in a state of fusion. In the meantime, I have prepared an ordinary voltaic battery of copper and amalgamated zinc charged with acidulated water, one part sulphuric acid to twenty-five parts water. To the positive wire of the battery, I attach an iron rod, having riveted at right angles to its extremity a flat disc of iron, the disc being a little smaller than the inner circumference of the crucible. To the negative wire of the battery I attach a simple rod or bar of iron. The matter in the crucible

being in a state of fusion and well fluxed, I place the above-mentioned disc of iron, which will now form the positive pole of the battery, on the surface of the fused mass, and keep the rod which is connected with the negative pole in contact with the outside of the crucible, the bottom of which thus forms the negative pole. The fused matter now forms a portion of the electric circuit; and the heat being kept up, the metal is gradually reduced and deposited at the bottom of the crucible."

The battery employed by Napier consisted of five pairs of plates for every hundredweight of regulus of thirty per cent. of metal. The internal resistance of the battery was quite low, as will be seen from the dimensions of the plates: "The size of zinc plates being three feet square, and the copper being doubled round the zinc in the usual way."

Napier did not limit himself to the use of the particular character or size of battery described. He says in the specifications of the patents before referred to: "The power of the voltaic battery, or other means of generating electricity which may be used, will vary for different ores, and I have found that if a larger battery be employed with the same quantity of ore, the time required for the extraction of the metal will be shorter, and *vice versa;* and if a more powerful voltaic combination be used a smaller sized battery or a shorter time will suffice."

The following additional details are given concerning the process: "Whether a crucible or other vessel or furnace be employed to contain the fused ore, it should have its bottom, or a sufficient portion of it at the lowest part, formed in the interior of plumbago or other suitable electro-conducting material with which the negative rod can come in contact. The positive pole should consist of an electro-conducting material, and I have found iron, as above described, the most convenient and satisfactory, although I have also found that coke may be used. The thickness of the wires or straps of metal used for connection should increase with the size of the apparatus. For the proportions above given I have found straps of ordinary sheet copper of an inch broad sufficient."

Structurally, the Napier electric furnace consists of the following elements in combination:

(1) A crucible or other receptacle of refractory material that is at the same time a conductor of electricity.

(2) A lining or luting applied to the inside of such crucible so as to necessitate the passage of the decomposing current through the melted mass to be treated.

(3) The combination with such a crucible of an external source of heat.

(4) The combination with the fused ore, contained in the crucible before mentioned, of the electrodes of a fairly powerful voltaic battery, or other electric source, so connected with the crucible as to permit the current to pass through the fused mass.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, *February 3, 1888.*

THE WELSBACH SYSTEM OF ILLUMINATION.

BY A. O. GRANGER.

[*Read at the Stated Meeting of the* INSTITUTE, *Wednesday, March 21, 1888.*]

W. P. TATHAM, Vice-President, in the Chair.

About the year 1880, Carl Auer, then a pupil of Prof. Bunsen at the University of Heidelberg, became interested in the subject of illumination. Bunsen particularly impressed upon Auer's mind that the present method of obtaining illumination from combustion of gas in the ordinary way, in which the separated carbon particles are made incandescent through the heat produced by the combustion of the hydrogen, was far from being economical, inasmuch as the amount of light yielded was but a small percentage of the energy contained in the gas, and gave it as his opinion that the light of the future would be obtained by first converting the illuminating gas into a heating flame through the medium of the well-known burner bearing his name, and then applying the heat so produced to bring to incandescence some refractory material. Young Auer revolved this suggestion in his mind, but before he had succeeded in obtaining any practical result the electric light changed the current of his thoughts. As is well known, in order to produce the incandescent electric light it is necessary that the carbon filament be used in a vacuum. Auer saw the expensiveness of this method,

and began a series of experiments to produce a filament made from refractory earths or oxides that could be used in the open air without being consumed. It was while engaged upon experiments of this nature that he produced the incandescent gas light now before you.

We all know that the idea of an incandescent light is not new, and every school-boy knows of the Drummond oxy-hydrogen lime light, but all lights of that character have failed to come into commercial use, because the material to be acted upon by the heat has always been present in considerable mass, and has required gas under pressure and a very high temperature to bring the mass to incandescence. But the Welsbach light is successful, because the oxides are produced in an extremely thin or attenuated form whereby the minimum of heat will produce the maximum of light.

Here is a complete burner, *Fig. 1* (*see frontispiece*). I will light it with the electric taper, and, of course, when that can be used, a match or any other competent source of heat will ignite the gas. You see, there is practically no explosion; in fact, there is less noise than in lighting an Argand burner.

I will describe the Welsbach burner very briefly: We use a modified, but very perfect form of the Bunsen burner (*Fig. 2*), the heat from which brings to incandescence the hood or mantle. This mantle, such as we have here (exhibiting), is knitted by machinery from fine cotton thread into a cylinder about 2 inches in diameter by 5 inches long. You see, it is soft and limp (*Fig. 3*). It is then dipped to the point of complete saturation in the chemical solution, which I will presently refer to, and then it is dried and attached by means of fine platinum wire to this vertical iron rod (exhibiting), with the horizontal loop at the top. Here is a mantle that has been saturated (exhibiting) and is all ready for the burning-out process, which consists in holding it over a Bunsen or a water-gas flame, whereby the cotton fibre is completely consumed, leaving nothing but the oxides that had adhered to the cotton (shrunken to about half the former size of the mantle, see *Fig. 4*) in the form of an extremely fine but coherent and refractory mineral skeleton, which perfectly retains the texture of the woven fabric. This is one of the great secrets of the success of the Welsbach system; no other method that at all approaches this having ever been discovered whereby an extremely small

amount of refractory material can be made to cover in a practical way so much surface.

There are three principal elements used in the manufacture of the solution in which the cotton cylinder or mantle is dipped, viz: lanthanum, zirconium and yttrium. These are produced respectively from the minerals cerite, zircon and samarskite, which are found in large quantities in Norway, Sweden, Ceylon, the Ural Mountains, and in our own country in North Carolina and elsewhere.

We have here some fine samples of the ores or minerals, and I will be glad to have anyone interested inspect them, as also the burners, etc., at the close of the meeting.

Heretofore these minerals have been considered very rare, and so they were so long as the only demand for them was for the collections of chemists and mineralogists. Now we can produce these crystals by the shovelful, and the cost of the oxides in one of these beautiful burners is but a few cents.

I will not weary you with the details of the method of reducing the ores to obtain these oxides as nearly chemically pure as possible, and will merely state that the result of the various operations employed is before us in the impalpable powder, of which we have here (exhibiting) a good sample, and from which the final impregnating solution is made by using certain proportions of the minerals.

Here is a bottle of the solution (exhibiting). It has a milky look, as you see, rather like lime water, and it is only necessary to vary the proportions of the oxides to produce any light from an intense white to a brilliant yellow.

The Welsbach patents were first acquired by the United Gas Improvement Company, of this city, and the original purchasers afterwards formed the Welsbach Company that now owns the system for the United States. It was early determined, after the managers had been fully satisfied in every particular as to the burner, to lay out plans and make an investment on a generous scale, and not to put any burners on the market until a considerable stock had been accumulated, so as to meet the large demand that was sure to come.

The Welsbach Incandescent Gas Light Company has a large factory at Gloucester, N. J., where the buildings cover some three

acres of ground. The company is introducing machinery and organizing its force to make 25,000 to 30,000 complete burners per day. It has erected its own fuel gas works, and, besides the machinery and apparatus for reducing minerals, has a complete chemical laboratory, machine shop, elaborate photometrical rooms, etc.

The working force is so organized that each step in the manufacture is carried on in a separate room. First comes the knitting of the mantle by machinery, and then a corps of girls attend to what is called the reinforcing or folding the mantle over at the top so as to have a larger amount of material through which to thread the platinum wire from which the mantle is suspended. The mantle is dipped in the solution and goes through a drying room, and then to the forming room, where it is given its shape, and then to the burning-out room, where the cotton is entirely consumed, leaving the refractory skeleton of the fabric behind, preserving intact the shape and appearance of the knitted cotton mantle. It is then mounted on the brass work or gallery, and we have the complete burner. For purposes of shipment the mantle, after having been burned as described, is dipped in a solution that entirely prevents any damage in transit.

Now, in introducing any new system of illumination, there are certain conditions necessary to success, and they must be recognized and fully covered.

(1) The brackets, chandeliers and gas fixtures that are in ordinary use must not be interfered with in any material way, and illustrating this point I will ask my assistant, Mr. Crisfield, to put one of these burners on that bracket on the wall (indicating).

There is an ordinary bracket, and an old-fashioned gas burner. You will see the facility with which the old burner is taken off and the Welsbach burner put on, only a few moments of time being required. (The change was made as Mr. Granger spoke.)

(2) The new burners must give a brighter, steadier and in every way a better light than the ordinary gas flame, so that the improvement will be decided at once upon seeing it. I think that point has also been covered and must be apparent to all present. (Pointing to the burners.)

Relative to the feature of economy, of which I will speak a little later, I will ask Dr. Wahl to kindly take a reading of these

burners to find the amount of gas used by the Welsbach and by the ordinary jet. Here is the meter and stop-watch.

(While Dr. Wahl was making the reading Mr. Granger continued):

(3) Any new burner coming before the public must also be easily lighted, easily taken care of, not liable to special derangement in ordinary practice or handling, and the cost of renewals must be moderate. This burner, while it is a mere skeleton, a mere ash, will stand all the banging it would get in ordinary use, and can be lighted just as easily as an Argand burner, with a match, or in any other way. (Illustrating by vigorously shaking a burner and then lighting it with an electric taper.)

(4) There should also be—and this point should be marked well—less vitiation of the atmosphere of the room. We all know that the combustion of gas in the ordinary way is imperfect, resulting in considerable vitiation of the atmosphere, and particles of carbon are set free as smoke or soot, but with the Bunsen flame this great objection is done away with, and there is also less oxygen consumed by reason of the reduced amount of gas burned.

(5) And above all, economy. While we may have a light that will radiate less heat—one that will give a perfectly white light, so that colors can be detected at night—a steady light, not affected by draughts, and a light that is more beneficial to health and in every way pleasanter and more desirable—yet if it possesses no economy in the use of gas, it will not find public favor to a large extent. In this burner we have no hesitation in asserting that with any kind of illuminating gas there is an efficiency of at least two to one in favor of the Welsbach burner. In other words, two and a half feet of coal gas consumed with the Welsbach burner will give a better light than five to six feet of gas consumed in the ordinary way. Now, to apply that practically in Philadelphia: Our coal gas is sold at $1.50 per 1,000 feet. With the Welsbach burner the gas would be less than seventy-five cents. That's not very scientific, but it is eminently practical.

Dr. Wahl says the ordinary gas jet is burning nearly eight feet, while about two and three-quarter feet are being consumed by this Welsbach burner.

[Although the meter reading had been made with great care, Dr. Wahl, being surprised at the result, said he would like to take

another reading of the ordinary gas jet, causing Mr. Granger to exclaim *sotto-voce*, "Give the gas a chance," which was received with much laughter.]

Dr. GOLDSMITH :—I would like to ask how you account for the cohesion? Is there an interlocking of the particles, or fusion?

Mr. GRANGER :—No, there is no fusion. As you see, this mantle is a reticulated mesh work, and when the cotton is entirely burned away, we have a perfect oxide copy of its former shape—a mere shadow, but there is, nevertheless, a certain amount of cohesion of the particles that make them hold together.

Dr. GOLDSMITH :—That is what I wanted to get at.

Mr. GRANGER :—That is one of the great points in this system. Others have attempted to produce an incandescent light, but the material while enduring a few hours, would disintegrate and fall to pieces, but there are certain elements used in the manufacture of this solution that give a toughness to the mantle which is very remarkable.

Dr. GOLDSMITH :—I can readily understand it if any fusion takes place of any elements, but it puzzled me to see how they otherwise held together, at first.

Mr. GRANGER :—It is a decided advance, and is only accomplished by certain chemicals that produce that result. There is, however, no fusion of the particles. We have not heat enough in the gas flame to fuse them.

Dr. WAHL :—The meter readings hold about the same relation to each other as before.

Mr. GRANGER :—While Dr. Wahl is completing that reading, I would say that I was recently in New York City, at the home of a friend, who is a Director of the Welsbach Incandescent Gas Light Company of New York, and he had on a side wall-bracket two Welsbach burners, each in a shade or globe similar to this (indicating), and below the bracket was a decorated plate (or plaque as I suppose the ladies would call it), set in a velvet frame, and this was hanging from the gas bracket by a little silvered wire, and a friend was there looking at the beautiful light. He seemed a good deal puzzled—looked at it a moment, and then said: "Does the current come up these wires?" (Merriment.)

A MEMBER :—What is the average life of the mantle?

Mr. GRANGER:—About 500 to 1,000 hours, or about six months of ordinary use, represented by the 500 hours.

I would like also to refer to one other point. I have a letter here from Prof. A. M. Mayer, of the Stevens Institute of Technology, whom many of you doubtless know, addressed to Mr. Shapleigh, who is the superintendent and chemist of the Welsbach Company's works at Gloucester. He says:

"One of the Welsbach burners I had handed me by Prof. Morton, who has several of them. I have been making experiments on it. Among other valuable properties for a lecturer and for researches in physics is the fact that it has furnished me at last, after many trials with other sources of radiant heat, with a source which is so constant that when placed before a Melloni thermo-pile it causes a deflection of the Thomson galvanometer (connected with the pile) which is absolutely constant, so that the reflected beam of light from the galvanometer remains in one fixed position on the screen. This lamp will hereafter be a requisite for all of these thermo-electric instruments."

I will now light the different burners so that you can see the variation in color. We have hardly pressure enough here to run all the burners, the gas having to pass through the rubber tube and test meter, but you see there is a white light, and this is the yellow. I will light this one so that you can see the effect of the globe or shade. (Does so.)

Dr. WAHL:—I would like to ask whether you have experimented as to the resistance of the filament to withstand a jar or shock given to the brackets, to determine whether or not by any accidental shaking, or any knock that it would be likely to get in use, it would be injured?

Mr. GRANGER:—In reply to that question I would say that I recently saw a statement made by the editor of a London scientific journal that he understood these mantles to be so fragile, that the least vibration, even that amount produced by a heavily-loaded team passing in the street, would disintegrate the mantle. This is the best answer to that statement (tapping the burner sharply several times), and I don't think that in ordinary use, unless a person went at it intending to break it, it would ever receive rougher handling than I have just given it, and so we hold that it is practical for ordinary use.

I would also say that this burner is quite an improvement over the burner that was brought to the attention of the United Gas Improvement Company a year ago. Then, a chimney was required

several inches taller than this, and of the pattern or style known as the Student lamp chimney, having a constricted portion here (indicating), and the burner was rather troublesome to light, requiring some skill. You had to turn it just so, and put the match at the right place just at the right time; but all that has been overcome now, and we use the Argand chimney of commerce; you can light it and use it just the same as any other burner, and hence we feel that it is now a practical success. I would say for the information of my hearers that in a few weeks the Philadelphia Welsbach Company will open its rooms at 122 South Twelfth Street, where there will be a number of burners on exhibition, both white and yellow, and also burners used with fuel gas.

We have here a small tank of fuel water gas (hydrogen and carbonic oxide) made at our works in Gloucester, from the decomposition of steam by passing it through a bed of glowing anthracite coal. I will ask my assistant, Mr. Beard, to turn on the gas, so that we can light this burner. (Exhibits the burner with fuel gas.)

Dr. Wahl (noticing the ease with which Mr. Granger lighted the burner from the top) said: "It seems to me that one of the best evidences of the practicability of the Welsbach filament is the fact that it can be lighted from above. There is a certain amount of explosive mixture formed in that chimney, and, as is well known, when the attempt is made to light it, it ignites with a slight explosion—and the fact that the filament will stand that sort of treatment seems to me a point in its favor. I am surprised to see the filament holding out and behaving as it does, because in reading of it I was led to believe that it was extremely fragile.

Mr. Granger:—We have here a very good form of Prof. Bunsen's burner, with a modified tip, so that there is almost no audible explosion and we are not troubled with lighting back, which is a very great fault in the ordinary Bunsen. There (pointing) we have a fine light with the fuel gas, and we have made experiments with this burner with natural gas, and find, in Pittsburgh, that we get twelve candles per foot. From the ordinary city gas here (coal gas) we get about eight candles per foot, so that the range may be said to be from eight candles per foot with coal gas to twelve candles per foot with natural gas. We have also tested it with gas produced by the Springfield and other gas machines, and get practically the same result as we have here,

showing that the burner is adapted to anything in the way of vapor or gas that contains sufficient heat.

Photographs have also been taken at night with this burner, and with an exposure of from one and a half to two minutes, negatives have been produced equal in every particular to the best sun negatives, showing that the actinic properties of the light are very perfect.

Mr. TATHAM:—How low can you turn it down without putting it out?

[Mr. Granger turned a burner down so low that some person in the audience said: "It's out." But it was not out, as was shown by turning the gas on, when the brilliant light instantly reappeared.]

Mr. Ives then projected the burner and mantle on the screen, greatly enlarged, after which the discussion was closed.

GENERAL THEORY OF JOINTED BOW GIRDERS.

BY E. A. WERNER, C.E.

PART I.—EXTERNAL FORCES.

Any structure is a system of material points acted upon by external and internal or elastical forces, which is subject to certain conditions—in our case to the condition to remain on certain points or planes—the abutments. All the forces acting upon the structure must be in equilibrium, when the structure shall resist the action of these forces.

Now, we know that the conditions of equilibrium of a free, rigid system of material points acted upon by forces can be expressed mathematically and that any system can be turned into a free, rigid system, in making the forces homogeneous and replacing the conditions to which it might be subject by forces of the same kind.

Hence in order to apply to any structure mathematical calculation, it is necessary to transform it into a free, rigid system, by expressing the internal or elastical forces and the conditions, that the structure has to remain upon the abutments by external forces.

This is done by substituting for the abutments their reactions and by cutting the structure at any point into *two* parts, removing one part and replacing its internal forces by external ones in the section. Which of the parts of the structure is removed does not matter, as both systems of external forces, acting upon the parts of the structure separated by the section, are *necessarily* in equilibrium by means of the equal but inversely directed internal or elastical forces.

If we express then mathematically the deformations of the structure produced by the action of the forces and add the conditions that all the forces are in equilibrium, we can—the form of the structure and the way of loading being known—finally express these forces themselves in mathematical form and subject them to numeric calculation.

But as all the structures, we have to deal with, are structures lying in a plane and remaining in this plane under the action of the loads, it is evident that, for our use, the above quite general problem may be restricted without detriment. Calling "line of thrust," the geometrical locus of the point of application of the thrust in the structure, the following disquisitions are thus conducted under the supposition that: "*the line of thrust be a plane curve and remain a plane curve under the action of the forces or loads.*"

If we assume now, as it is generally accepted, that the normal and tangential (shearing) forces produce strains equally distributed over the elements of the section, and that the moments produce, parallel to the axis of bending, equal but increasing strains in ratio with the distance from this line in the sections of the structure, we know that the conditions, which must be fulfilled to comply with the assumption of a plane line of thrust, remaining a plane curve under the action of the forces or loads, are:

(1) *The plane of the line of thrust must be a plane of symmetry of the whole structure; and*

(2) *The external forces—the loads and reactions of the abutments—must act in the plane of the line of thrust.*

We have then, according to the above premises, for expressing the forces in the structure the equations of equilibrium of a free rigid system.

Referring the system to a rectangular system of co-ordinates, with the origin lying in the left abutment and the X axis passing through the abutment joints, these equations are:

$$\Sigma (x) - H = o$$
$$\Sigma (y) - V = o$$
$$\Sigma (x\ y) - M = o$$

wherein:

$\Sigma (x)$, $\Sigma (y)$, $\Sigma (x\ y)$ represent the sum of all the internal forces of the removed part in the direction of the X and Y axis and their moments, and H, V, M, the same sums with regard to the external forces—the loads and the reactions of the abutments.

These equations give the internal or elastical forces $\Sigma (x)$, $\Sigma (y)$, $\Sigma (x\ y)$ as functions of the external ones, and I must first show how those external forces can be expressed in mathematical form, and their maximal and minimal values found.

1. EXTERNAL FORCES.

The following denominations and assumptions will be made:

The structure shall always have three joints, one on each abutment and one somewhere else between the abutments. I shall always call A the left abutment, B the right abutment, C the top joint, and suppose the latter to lie in the middle of the span. In the rare cases, when this is not so, it will be easy to make the necessary corrections.

The line of thrust is the geometrical locus of the points of application of the thrust in the structure. The line of thrust shall always be a plane curve, of such shape, *that a line parallel to a line connecting top and abutment joint* $A\ C$ or $B\ C$ shall have *no more than one point of contact in each half bow.*

The line of thrust shall always remain a plane curve under the action of the loads.

The line of thrust shall be referred to a rectangular system of co-ordinates, with the origin in the left abutment and the X axis passing through the two abutment joints.

No restriction is made as to the way of loading the structure or the numeric value of the loads.

The structure is supposed to be loaded quite arbitrary with loads at rest and moving loads, both kinds single or together, covering in any way the whole or parts of the structure, continuously or in single points.

G_1 be the sum of all the loads from the left abutment, to a point $x_m\, y_m$.

G_2 the same sum, from the point $x_m\, y_m$ to the top joint.

G_3 the same sum from the top joint to the right abutment.

$g_1\, g_2\, g_3$ be the abscissæ of the point of application of $G_1\, G_2\, G_3$.

I shall always represent the loading, regardless to the way of loading or the numeric value of the loads, in using for *moving loads a heavy line,* for *loads at rest a light line, extending over the whole space covered with loads.*

ACB = the line of thrust.

l = span of the structure, centre to centre of joints A, B.

f = height of the top joint C above the abutment joints A, B.

Δx_m = length of th mth panel.

μ_m = angle of the tangent of the line of thrust in the point $x_m\, y_m$ with the X axis.

μ_f = angle of the line $A\,C$ or $B\,C$ with the X axis.

Q, Q_1 = the vertical component of the abutment reactions.

H = the horizontal component of the abutment reactions.

V_m = sum of the vertical shearing forces, *without the component of the thrust* in the point $x_m\, y_m$ (vertical shearing forces of a beam of the same span and loading).

R_m = sum of the shearing forces *normal* to the line of thrust in the point $x_m\, y_m$.

S_m = sum of the *vertical* shearing forces in the point $x_m\, y_m$.

M_m = sum of the moments of all the forces in the point $x_m\, y_m$.

m is an index, defining the position of the point under consideration $x_m\, y_m$ I shall count from the left abutment, 1. 2. 3. . . . . m, $(m+1)$, $(m+2)$ . . . . . . $(n-2)$, $(n-1)-n$.

With these denominations we have now directly from *Fig. 1* of *Plate I:*

$$Q_1 = \frac{G_1\, g_1 + G_2\, g_2 + G_3\, g_3}{l} \tag{1}$$

$$Q = G_1 + G_2 + G_3 - Q_1 = \frac{G_1(l-g_1) + G_2\,(l-g_2) - G_3(l-g_3)}{l}$$

$$Hf = Q_1\,\frac{l}{2} - G_3\left(\frac{l}{2} - g_3\right) = Q\,\frac{l}{2} - G_1\left(\frac{l}{2} - g_1\right) -$$

$$- G_2\left(\frac{l}{2} - g_2\right) \tag{2}$$

$$H = \frac{G_1 g_1 + G_2 g_2 + G_3 (l - g_3)}{2f} \tag{3}$$

$$M_m = Q x_m - G_1 (x - g_1)_m - H y_m = Q_1 (l - x)_m - G_2 (g_2 - x)_m - \\ - G_3 (g_3 - x)_m - H y_m \tag{4}$$

$$M_m = G_1 g_1 \left(1 - \frac{2fx + ly}{2fl}\right)_m - G_2 \left(x - g_2 \frac{2fx + ly}{2fl}\right)_m \\ + G_3 (l - g_3) \left(\frac{2fx - ly}{2fl}\right)_m \tag{5}$$

(See *Fig. 2.*)

$$V_m = Q - g_1$$

$$R_m = V_m \cos \mu_m - H \sin \mu_m$$

$$S_m = \frac{R_m}{\cos \mu_m} = V_m - H \operatorname{tng} \mu_m \tag{6}$$

$$S_m = - G_1 g_1 \left(\frac{1}{l} + \frac{\operatorname{tng} \mu_x}{2f}\right)_m + G_2 \left(1 - g_2 \frac{\operatorname{tng} \mu_x}{2f}\right)_m - \\ + G_3 (l - g_3) \left(\frac{1}{l} - \frac{\operatorname{tng} \mu_x}{2f}\right)_m \tag{7}$$

and as known:

$$S_m = \frac{dM}{dx} = \frac{M_m - M_{m-1}}{\Delta x_m} \tag{8}$$

The above equations give the external forces of a jointed bow structure in mathematical form, and I will now show, how the positions of the loads inducing their maximal and minimal values are found.

$Q\ Q_1\ H =$ Reactions of the abutments.

For loads at rest, the reactions of the abutments are constant.

For moving loads, they increase with increasing loading and reach their maximal values with a completely loaded girder and *vice versa* for the minimal values.

But quite generally *H increases* with *decreasing* height of the bow.

MOMENTS.

Loads at rest.

We know that quite generally:

$$S_m = \frac{dM}{dx} = \frac{M_m - M_{m-1}}{\Delta x_m}$$

Hence M is a maximum in all points in which $S_m = o$ or in all points in which:

$$o = V_m - H \, tng \, \mu_m$$

or:

$$o = \frac{f}{\frac{l}{2}} \cdot \frac{-G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 (l - g_3)} - tng \, \mu_m \quad (9)$$

The general course of the moments is thus as follows:

M always is zero in the abutment and top joints, between which it reaches as many maxima or minima as the above equation has roots. The number of these roots depends upon the way of loading and the form of the line of thrust.

I will first consider the maxima and minima depending upon the form of the line of thrust.

We deduct from equation (9):

$$tng \, \mu_m = tng \, \mu_f = \frac{f}{\frac{l}{2}} \quad (10)$$

This expression is easily constructed. It represents the point of contact with the line of thrust of a line parallel to $A\ C$ or $B\ C$ (see *Fig. 3*). As often as the parallel to $A\ C$ or $B\ C$ is tangent on the line of thrust as many maxima or minima of M will occur and in as many parts, comporting all alike, the structure will be divided. (*Fig. 4.*)

I have thus assumed that the form of the line of thrust is such, that a parallel to $A\ C$ or $B\ C$ has only one point of contact in each half bow. In case of more than *one* point of contact the results obtained under the above assumption must be applied to each of the subdivisions of the girder separately.

The other roots of equation

$$V_m - H \, tng \, \mu_m = o$$

depend upon the way of loading and the value of the loads. They cannot be pointed out *a priori*, but it will never present any difficulty to find them for any specified loading. For the rest, they occur only for *quite* special loadings.

Under ordinary circumstances, the only maximum and minimum of M occuring is that corresponding to:

$$tng \, \mu_m = tng \, \mu_f$$

In using the values of M as ordinates, the changes of M from point to point in the structure can be graphically represented. *Fig. 5* shows the shape of the curve of the moments in a structure, with only positive or only negative moments. *Fig. 6*, in a structure with alternative positive and negative moments.

MOVING LOADS.

With moving loads the value of the moments will not only change from point to point in the structure, but also with any new position of the loads. Still, in considering first a certain point in the girder, that is, in making $x_m\ y_m$ constant, we can find the variations of M in the point under consideration, while the loads are passing over the structure and in applying the resulting rules to every point in the structure deduct the general rules governing the positions of the loads, inducing the maximal and minimal values of the moments in each point of the structure.

Eq. (5).

$$M_m = G_1 g_1 \left(1 - \frac{2fx + ly}{2fl}\right) + G_2 \left(x - g_2 \frac{2fx + ly}{2fl}\right) +$$
$$+ G_3 (l - g_3) \left(\frac{2fx - ly}{2fl}\right)$$

is of little use in the above form for these investigations and must thus first be brought in a more convenient form by transforming the coefficients of $G_1\ G_2\ G_3$:

$$\left(1 - \frac{2fx + ly}{2fl}\right) = a \qquad (11^a)$$

$$\left(x - \frac{2fx + ly}{2fl} g_2\right) = b \qquad (12^a)$$

$$\frac{2fx - ly}{2fl} = c \qquad (13^a)$$

I shall call these coefficients henceforth a . b . c.

For the transformation, I shall introduce an auxiliary figure by drawing the lines $A\ C$, $D\ C$, connecting the abutment and top joints and $A\ C$ the perpendicular in A (*Fig. 7*), or the triangle $D\ A\ C$.

I shall call this triangle henceforth the "*deciding triangle*," as the position of the line of thrust, with regard to this triangle,

decides of the way, in which the moments, or in fact, as we will see, all the forces are acting in the structure.

I shall call then, furthermore:

ζ' = ordinate of the line $D\ C$.

ζ = ordinate of the line $A\ C$.

Then:

$$a = \left(1 - \frac{2fx + ly}{2fl}\right) = \frac{\zeta' - y}{2f} \qquad (11)$$

$$b = \frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f} \qquad (12)$$

$$c = \frac{2fx - ly}{2fl} = \frac{\zeta - y}{2f} \qquad (13)$$

Still b can be expressed in another way, which will prove most useful, in introducing an auxiliary quantity.

If we consider b, we see, that it depends upon x and g_2. But for—

$$g_2 = g_m = \frac{2flx}{2fx + ly} \qquad (\mathrm{I}\ )$$

it becomes zero.

g_m as a and c is simply a function of $x_m\ y_m$ or of the form of the line of thrust and can consequently be graphically constructed. g_m is the abscissa of the point of intersection of the two lines $D\ C$ (the upper side of the deciding triangle) and $A\ y$.

The demonstration follows directly from the figure (*Fig. 8*).

In introducing g_m in $a\ b\ c$, we have then the following three forms of M:

$$M_m = a_m G_1 g_1 + b_m G_2 + c_m G_3 (l - g_3) \qquad (\mathrm{I}$$

$$M_m = G_1 g_1 \left(\frac{\zeta' - y}{2f}\right)_m + G_2 \left(x - \frac{\zeta + y}{2f} g_2\right)_m + G_3 (l - g_3) \left(\frac{\zeta - y}{2f}\right)_m \qquad (\mathrm{I^a})$$

$$M_m = \frac{1}{g_m} (g_m - x) G_1 g_1 + G_2 (g_m - g_2) \frac{x}{g_m} + G_3 (l - g_3) \left(\frac{2 g_m - l}{l}\right) \frac{x}{g_m}\ {}_m \qquad (\mathrm{I^b})$$

Equations (I) are the *pivot* equations of the whole theory. The expressions of all the other forces can be reduced to them.

The positions of the loads inducing the maximal and minimal positions of the moments are now found by investigating the action and influence of the different factors composing the total value of M.

If we consider to that effect Eq. I, we see that the total value of M depends upon *two* quite different factors:

(1) $G_1\ G_2\ G_3$ representing the way of loading and the numeric value of the loads. These quantities are *independent* of the form of the line of thrust, and

(2) $a.\ b.\ c.$, functions of y and ζ, representing the influence of the form of the line of thrust and of the deciding triangle.

The influence of $G_1\ G_2\ G_3$, the first factor is easily explained.

$G_1\ G_2\ G_3$ are functions of the loads only and necessarily always positive, changing only their numeric values. The absolute value of the moments will thus only be influenced so far, as its numeric value will be greater or smaller accordingly as $G_1\ G_2\ G_3$ are greater or smaller.

The influence of the second factor, or of the coefficients $a\ b\ c$, is not so simple. It is *two-fold*, as not only the coefficients can assume any absolute value, but also can become *positive* or *negative*.

The influence of the absolute value of $a\ b\ c$ upon the total value of M is similar to that of $G_1\ G_2\ G_3$. The greater $a\ b\ c$, the greater M and *vice versa*.

Quite different is the influence of the signs of $a\ b\ c$ upon the total value of M.

As $G_1\ G_2\ G_3$ are always positive, *the signs of $a\ b\ c$ decide the sign of the total value of the moments or the way, in which the moments are acting in the structure.* The signs of $a\ b\ c$ are thus the principal factors in deciding the total value of the moments and their maximal and minimal values.

The signs of $a\ b\ c$ depend upon y and ζ. Hence in considering a certain point $x_m\ y_m$ in the structure,—$x_m\ y_m$ is then constant,—and in varying the form of the line of thrust, we will find the alterations of $a\ b\ c$ in the point under consideration. To that effect $A_1\ C$, $A_2\ C$, $A_3\ C$, $A_4\ C$ represent in *Fig. 9* different forms of the line of thrust, $x_m\ y_m$ be the point under consideration. $D\ A\ C$ the deciding triangle.

Then:

$$a = \frac{\zeta^1 - y}{2f}$$

is positive or negative accordingly, as:

$$\zeta^1 \gtrless y$$

or a is:

positive in all structures, whose lines of thrust lie *inside* or *below* the deciding triangle; *negative* in all structures, whose lines of thrust lie *above* the deciding triangle; *zero* in all structures, whose lines of thrust *coincide* with the side $D\ C$ of the deciding triangle.

$$c = \frac{\zeta - y}{2f}$$

is positive or negative accordingly, as:

$$\zeta \lessgtr y$$

or c is:

positive in all structures, whose lines of thrust lie *below* the deciding triangle; *negative* in all structures, whose lines of thrust lie *inside or above* the deciding triangle; *zero* in all structures, whose lines of thrust *coincide* with the side $A\ C$ of the deciding triangle.

The *sign of* b depends upon the value of g_m. The value of g_m will be:

(1) When the line of thrust lies *above* the deciding triangle

$$g_m < x_m$$

and

$$b = (g_m - g_2)\frac{x_m}{g_m} < 1$$

or *negative*, g_2 being necessarily, according to the premises, greater than x_m.

(2) When the line of thrust *coincides* with the line $D\ C$ of the deciding triangle

$$g_m = x_m$$

and

$$b = (x_m - g_2) < 1$$

or *negative*.

b is still negative, but independent of the form of the line of thrust g_m, depending only upon the way of loading g_2.

(3) When the line of thrust lies *inside*, the deciding triangle

$$x_m < g_m < \frac{l}{2}$$

and

$$b = \frac{x_m}{g_m}(g_m - g_2) \gtrless 1$$

accordingly as:

$$g_2 \lessgtr g_m$$

b *is positive or negative* accordingly as g_2 is smaller or greater than g_m.

(4) When the line of thrust lies below the deciding triangle

$$\frac{l}{2} < g_m < l$$

and

$$b = \frac{x_m}{g_m}(g_m - g_2) > 1$$

or *positive*, as g_2 always is smaller than $\frac{l}{2}$

(5) When the line of thrust *coincides* with *the side* $A\ C$ of the deciding triangle

$$g_m = \frac{l}{2}$$

and

$$b = \frac{x_m}{\frac{l}{2}}\left(\frac{l}{2} - g_2\right)$$

or *positive.*

(6) When the line of thrust *coincides* with the X axis

$$g_m = l$$

and

$$b = \frac{x_m}{l}(l - g_2)$$

or *positive.*

In both cases, when the line of thrust coincides with the side $A\ C$ of the deciding triangle, or with the X axis, b is *positive*, but

depending only upon the way of loading, and no more upon the form of the line of thrust.

(7) When the line of thrust lies *below* the X axis, y is then *negative* and the expression

$$b = \left(x - g_2 \frac{2fx + ly}{2fl}\right)_m = \left[\left(1 - \frac{g_2}{l}\right) x - \frac{y\,g_2}{2f}\right]_m$$

shows that b always is *positive*.

Resuming we have:

(1) The line of thrust lies *above* the deciding triangle.

$a \,.\, b \,.\, c$ are *negative*.

(2) The line of thrust lies *inside* the deciding triangle.

a is *positive*.

b *positive* or *negative*, accordingly as

$$g_2 \lessgtr g_m$$

c *negative*.

(3) The line of thrust lies *below* the deciding triangle.

$a \,.\, b \,.\, c$ are *positive*.

(4) The line of thrust (or points of it) *coincides* with the side $D\ C$ of the deciding triangle.

$$a = o$$

$$b.\ c.\ \textit{negative}.$$

(5) The line of thrust (or points of it) *coincides* with the side $A\ C$ of the deciding triangle.

$$a\ .\ b\ .\ \textit{positive}$$

$$c = o.$$

These results, which are completely independent of the way of loading or the value of the loads, show that *the signs of $a\ b\ c$ are decided, regardless to the form of the line of thrust and the way of loading, only and solely by the position of the line of thrust, with regard to the deciding triangle, in all cases but for structures, of which the lines of thrust lie inside the deciding triangle.* In the latter structures the sign of b, *but only of* b, depends upon the form (g_m) of the line of thrust and the way of loading (g_2). The total value of the moments depends thus principally upon the position of the line of thrust with regard to the deciding triangle, the absolute value of $a\ b\ c$ and of the loads $G_1\ G_2\ G_3$ having only an influence upon the numeric value of M.

These results show that, whatever be the way of loading or the numeric value of the loads, I can produce in any point of a structure, with exception of the joints, either positive or negative moments, whose absolute values will lie between $+\infty$ and $-\infty$, in selecting accordingly the position of the line of thrust with regard to the deciding triangle.

In any point x_m y_m of a structure the value of M, for $y = -\infty$ becomes $+\infty$. The line of thrust is concave against the X axis, lying below the X axis. With decreasing concavity of the line of thrust, the value of M is decreasing until $y = o$. Then the line of thrust begins to lie above the X axis. It is also concave against the X axis, but with increasing concavity, the value of M decreases, until for a line of thrust, *inside the deciding triangle, the value of M becomes zero.* If the line of thrust is then made more and more concave against the X axis the value of M will begin to become negative and grow negatively with increasing concavity of the line of thrust until for $y = +\infty$ M reaches the value of $-\infty$.

That the lines of thrust corresponding to $M = o$ must all lie *inside* the deciding triangle, whatever be the way of loading or the numeric value of the loads, will be readily understood, if we mind, that only for lines of thrust lying *inside* the deciding triangle b and c can become negative, while a is positive and consequently $M = o$.

The exact form of the line of thrust depends, of course, in each case upon the absolute value of a b c and G_1 G_2 G_3, and also, for the forms of the lines of thrust lying *inside* the deciding triangle upon the way of loading. For these forms inside the deciding triangle, a is positive, c negative and b either positive or negative, and it is evident that for any of these forms of the lines of thrust, a combination of loads can be found, making M to zero, but on the other side, it is also evident, that every position or numeric value of the loads, will command its own special form of the line of thrust, corresponding to the value $M = o$.

As we will see later the forms of the lines of thrust corresponding to the value $M = o$ are practically the most valuable ones.

These investigations give the means on hand to decide the signs of a b c for any form of the line of thrust, but for structures, of which the lines of thrust lie *inside the deciding* triangle.

In these structures the sign of b is either positive or negative, and it remains to show how in this case also the sign of b can be defined.

To that effect $A\ B\ C$ represent in *Fig. 10* the line of thrust of a jointed bow girder, lying *inside* the deciding triangle, with g_m answering the point $x_m\ y_m$ under consideration.

I will now suppose that the sum G_2 of all the loads covering the structure from x_m to the top joint C, be decomposed into its elements $p\ p'\ p''\ p''' \ldots\ldots p^n,\ p^{n+1}, \ldots\ldots p^r$, and that $\pi, \pi', \pi'', \pi''' \ldots\ldots \pi^n, - \pi^{n+1} \ldots\ldots \pi^r$ be the corresponding g_2; $p, p', p'' \ldots\ldots$ having any numeric value and being distributed over the part corresponding to G_2 in any quite arbitrary way. I shall then furthermore assume, that:

$$\pi^n \leqq g_m \text{ and } \pi^{n+1} \geqq g_m.$$

It will then be:

$$G_2 (g_m - g_2) \frac{x_m}{g_m} = \frac{x_m}{g_m} [p (g_m - \pi) + p' (g_m - \pi') +$$

$$+ \ldots p^n (g_m - \pi^n) + p^{n+1} (g_m - \pi^n) + \ldots\ldots p^r (g_m - \pi^r)\}$$

and

$$p (g_m - \pi)$$

represents the *increment of* $G_2 (g_m - g_2)$ from point to point.

This increment is positive as long as:

$$\pi < g_m$$

that is, until the loads cover the structure from x_m to g_m.

The next increment must be negative, as

$$\pi^{n+1} > g_m.$$

Hence:

$$\Sigma [p (g_m - \pi)] \frac{x_m}{g_m} = G_2 (g_m - g_2) \frac{x_m}{g_m}$$

will be positive and increase until the loads cover the girder from x_m to g_m and

$$G_2 (g_m - g_2) \frac{x_m}{g_m}$$

will thus reach a positive maximum, when the structure is covered with loads from x_m to g_m; regardless to the way of loading or the numeric value of the loads.

The ordinate corresponding to g_m is the parting line of the positive and negative increments of

$$G_2 (g_m - g_2) \frac{x_m}{g_m}.$$

I shall call henceforth g_m "*the maximum line of G_2.*"

The ordinates y and f, on the other hand, are parting lines of the loads.

$g_m - a$, as defined above, *is the length from x_m to the top joint,* which must be covered with loads, *to make*

$$G_2 (g_m - g_2) \frac{x_m}{g_m}$$

to a positive maximum. g_m represents thus *not* the length from x_m to the top joint, *answering positive values of*

$$G_2 (g_m - g_2) \frac{x_m}{g_m}.$$

The latter length is quite different from g_m, depending of the way of loading, whilst g_m is only and solely depending upon the form of the line of thrust. g_m does not decide the sign of b absolutely as the signs of a and c are decided; but g_m, as defined above, gives the length from x_m to the top joint, which must be covered with loads to reach a *maximum* of

$$G_2 (g_m - g_2) \frac{x_m}{g_m}$$

and in this respect answers the purpose of defining the position of the loads creating the maximal or minimal values of M.

With this we can decide for any form of the line of thrust the action and the influence of each of the factors making up the total value of M, upon this value, and I can thus proceed now to show how the positions of the loads creating the maximal and minimal values of M are found.

The way is simple.

As the total value of M consists of a sum of single factors, of which the absolute values and signs can be decided by means of the previous investigations, for any form of the line of thrust and kind of loading, we will evidently find the maximal value of M, in making the positive factors as great as possible, the negative fac-

tors as small as possible and *vice versa* for a minimal value of M, or, in other words:

"To find the maximal value of the moments, calculate or construct $a \cdot b \quad c$ and g_m, the maximum line of G_2, and fill those parts of the structure, corresponding to *positive* values of $a\,b\,c$ with loads, in selecting for $G_1\,G_2\,G_3$, the greatest values possible, and *vice versa* for the minimal value of M."

This rule is very simple and easy to apply. From it follows that in all structures whose lines of thrust lie *outside* the deciding triangle, including the sides $A\ C$ and $D\ C$ of the latter, the *maximum* of the moments is reached, by covering the structure *completely* with loads as shown in *Fig. 11*, of course, only for those points of the structure lying above and below the deciding triangle ($D\ C$).

In structures, whose lines of thrust lie *inside* the deciding triangle the *maximum* of M is reached in filling the spaces corresponding to a and g_m, and leaving $\left(\frac{l}{2} - g_m\right)$ and c empty as shown in *Fig. 12*.

In all cases the greatest possible values of $G_1\,G_2\,G_3$ being selected for the maximum of M.

The minimum of M is found in filling in the inverse sense the structure, as shown in *Fig. 13* and *Fig. 14*.

Should the line of thrust have more than *one* point of contact with a parallel to $A\ C$, or $B\ C$ in each half bow, the structure would be decomposed in parts corresponding to the number of points of contact. For instance, in *Fig. 15* in four parts ($\overline{G_1\,G_2}$ — G_3 — G_4) and

Eq. (1) would take the form:

$$M_m = a\,G_1\,g_1 + b\,G_2 + c\,G_3 + d\,G_4 + e\,G_5\,(l - g_3).$$

But it will present no difficulty to apply the above-shown methods, and to deduct the correct positions of the loads inducing the maximal and minimal values M.

The rules derived for loads at rest for the alterations of the values of M from point to point in the structure can also be applied to the above defined positions inducing the maximal and minimal values of M, each position being considered as a position of loads at rest. We will find in this way the envelop of all the

curves of the moments, and the *absolute greatest and smallest values of M*, and the point in the structure in which they occur.

In first line it is visible that these absolute maxima and minima of the moments must also comply with the equation $S_m = o$, or,

$$o = \frac{f}{\frac{l}{2}} \cdot \frac{- G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 g_3} - tng\, \mu_m$$

and if the line of thrust has only one point of contact with a parallel to $B\ C$ or $A\ C$ in each half bow, the only point answering the above conditions will be :

$$tng\, \mu_m = tng \frac{f}{\frac{l}{2}} = tng\, \mu_f \quad .$$

if we set apart the possibility of values from special loadings.

If I construct thus a parallel to $A\ C$ or $B\ C$, I shall have in the point of contact of this line with the line of thrust the point, in which the absolute maximum or minimum of M takes place. This point fixed, it will be only necessary to apply to it the method for defining the positions of the loads creating the maximum or minimum values of M, to decide the position of the loads generating the absolute maximum or minimum. In *Fig. 16* is shown the application for a line of thrust lying inside the deciding triangle, as in structures with lines of thrust lying outside the deciding triangle, the point in which the absolute maximum or minimum occurs, can only be defined, the position of the loads creating the maximum, being a fully loaded girder for all points.

The result is in so far curious, as it shows that the absolute maximal and minimal values of the moments in a girder under the assumed conditions, which are those met in practice, will occur in the point of contact of a parallel to $A\ C$ or $B\ C$ with the line of thrust, a point which depends only and solely upon the form of the line of thrust.

In reversing the above deducted methods, it will also be very easy to find the point in which the maximum or minimum of the moments occurs for any given loading.

Other points of absolute maximal or minimal values of M may occur from special loadings, yet they cannot be pointed out *a priori*, but will always easily be found for any specified loading.

Should the line of thrust have more than one point of contact with a parallel to $A\ C$ or $B\ C$, only the comparison of the different numeric values of the maxima and minima will give the absolute maximum or minimum of M.

SHEARING FORCES.

Loads at rest.—As we know $S = o$ gives the points corresponding to maximal and minimal values of M, $M = o$ will thus give the points corresponding to maximal and minimal values of S and the general course of the shearing forces from point to point in the structure is as follows:

The shearing forces have maxima and minima in the abutment and top joints and between these joints as many more as there are points, in which the equation $M = o$ is fulfilled, passing between two of these values each time through zero in the points corresponding to:

$$o = \frac{f}{\frac{l}{2}} \cdot \frac{-G_1 g_1 + G_2 (l - g_2) + G_3 (l - g_3)}{G_1 g_1 + G_2 g_2 + G_3 g_3} - tng\,\mu_m \quad (9)$$

In using the values of S as ordinates, the variations of S from point to point in the structure can also be graphically represented.

Fig. 17 shows the general aspect of the curve of the shearing forces, when the line of thrust has only one point of contact with a parallel to $A\ C$ or $B\ C$ in each half bow and the loads are *equally* distributed over the girder.

Should the line of thrust have more than *one* point of contact with a parallel to $B\ C$ or $A\ C$, the above curve would consist of as many parts, as there are values making S to zero.

MOVING LOADS.

We have:

$$S_m = - G_1 g_1 \left(\frac{1}{l} + \frac{tng\,\mu_x}{2f}\right)_m + G_2 \left[1 - g_2 \left(\frac{1}{l} + \frac{tng\,\mu_x}{2f}\right)\right]_m +$$

$$+ G_3 (l - G_3) \left(\frac{1}{l} - \frac{tng\,\mu_x}{2f}\right)_m$$

In introducing the same denominations as for the moments, we shall have:

$$(a_s)_m = \left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)_m = \left(\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m \quad (14)$$

$$(b_s)_m = \left[1 - g_2\left(\frac{1}{l} + \frac{tng\ \mu_x}{2f}\right)\right]_m = \left(1 - g_2\,\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m \quad (15)$$

$$(c_s)_m = \left(\frac{1}{l} - \frac{tng\ \mu_x}{2f}\right)_m = \left(\frac{tng\ \mu_f - tng\ \mu_x}{2f}\right)_m \quad (16)$$

which values are obtained in writing

$$\frac{f}{\frac{l}{2}} = tng\ \mu_f$$

The coefficient b can also be expressed in this case by introducing an auxiliary quantity making the value of b to zero.

$$g_2 = g_s = \left(\frac{2f}{tng\ \mu_f + tng\ \mu_x}\right)_m \quad (II^c)$$

g_s as g_m can easily be constructed.

g_s is the abscissa of the point of intersection of a parallel through A to the tangent in the point $x_m\ y_m$ of the line of thrust, with the line $B\ D$, the upper side of the deciding triangle as shown in *Fig. 19*.

The demonstration follows from the figure.

In introducing these values we have the following *three* forms of S_m:

$$S_m = a_s\ G_1 g_1 + b_s\ G_2 + c_s\ G_3\,(l - g_3) \quad \textbf{(II)}$$

$$S_m = -\ G_1\,g_1\left(\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m + G_2\left(1 - \right.$$

$$\left. - g_2\,\frac{tng\ \mu_f + tng\ \mu_x}{2f}\right)_m + G_3\,(l - g_3)\left(\frac{tng\ \mu_f - tng\ \mu_x}{2f}\right)_m \quad (II^a)$$

$$S_m = -\frac{1}{g_s} G_1\,g_1 + G_2(g_s - g_2)\frac{1}{g_s} + G_3\,(l - g_3)\left(\frac{2\,g_s - l}{l}\right)\frac{1}{g_s} \quad (II^b)$$

The value g_s has the same properties with regard to S as g_m with regard to M.

The ordinate of g_s is the parting line of the positive and negative increments of $G_2 (g_3 - g_2) \frac{1}{g_s}$ and the second member of eq. (II) will thus reach a *positive maximum*, when the loads cover the structure from x_m to g_s *regardless to the numeric value of the loads or the way of loading.* The demonstration is exactly the same as for g_m of the moments.

I shall call henceforth g_s *the maximum line of* G_2.

g_s as defined above gives the length from x_m to the top joint, which must be covered with loads to reach a positive maximum of $G_2 (g_s - g_2) \frac{1}{g_s}$ and answers thus, as g_m for the moments, the purpose of defining the position of the loads creating the maximal and minimal values of S_m.

If we consider now Eq. (II) we see that the total value of the shearing forces depends of the *same two factors* G_1 G_2 G_3 and a b c as the total value of the moments, these factors expressing in Eq. (II) exactly *in the same way the influence of the loads and of the form of the line of thrust with regard to the total value of the shearing forces*, as they do in eq. (I) with regard to the total value of the moments, differing only in their absolute value. The results of the investigations for defining the positions of the maximal and minimal values of the moments will thus be directly applicable to the shearing forces, and I have only to show how the signs of a b c can be defined for any form of the line thrust.

If we consider to that effect eq. (II) we see that the signs of a b c depend merely of the *value of* $tng\, \mu_m$.

If $tng\, \mu_m$ *is positive:*

a is negative, b has a positive maximum and c is positive or negative, accordingly as:

$$tng\, \mu_m \lessgtr tng\, \mu_f$$

If $tng\, \mu_m$ *is negative:*

a is positive or negative accordingly as:

$$tng\, \mu_m \gtrless tng\, \mu_f$$

b has a positive maximum or is positive, and c is positive.

These rules will give in every instance the correct sign of $a\,b\,c$, as it will always be very easy to decide whether $tng\,\mu_m \gtrless tng\,\mu_f$, μ_f being the angle between $A\,C$ or $B\,C$ and the X axis.

With this we can decide for any form of the line of thrust the action and the influence of the factors composing the total value of S, upon this value, and we shall find now the positions of the loads inducing the maximal and minimal values of S in the same way as for the moments, to wit:

"To find the maximal value of the shearing forces, calculate or construct $a\,b\,c$ and g_s the maximum line of G_2, and fill those parts of the structure corresponding to positive values of $a\,b\,c$ with loads, in selecting for $G_1\,G_2\,G_3$ the greatest values possible, and *vice versa*, for the minimal values of S."

Fig. 19 shows the application of this rule for a positive value of $tng\,\mu_m$, when $tng\,\mu_m > tng\,\mu_f$; a and c are then negative and only the positive maximum of G_2 is positive.

Fig. 20 shows the application also for a positive value of $tng\,\mu_m$, but $tng\,\mu_m < tng\,\mu_f$.

— a is then negative, $b > \frac{l}{2}$ and c positive.

Should the line of thrust have more than *one* point of contact with a parallel to $A\,C$ or $B\,C$ in each half bow, the structure would be decomposed in parts corresponding to the number of points of contact, and eq. (II) take the form:

$$S_m = (a_s)_m\,G_1\,g_1 + (b_s)_m\,G_2 + (c_s)_m\,G_3 + \ldots\ (p_s)_m\,G_3(l - g_3).$$

But it will present no difficulty in applying the above deducted rules to find in this case also the correct positions of the loads inducing the maximal and minimal values of S.

For special loadings, moreover, other maximal and minimal values of S can occur, but it will always be possible to define them easily for a specified loading.

With this, the positions of the loads inducing the maximal and minimal values of the moments and shearing forces can be defined in all instances in a very simple manner, as soon as I have explained how the point into consideration $x_m\,y_m$ goes into the parts G_1 or G_2.

In considering eq. (4)

$$M_m = Q x_m - G_1 (x_m - g_1) - H y_m$$

we see that:

"The point under consideration $x_m\, y_m$ forms a part of the first division G_1, while the top joint belongs to the third division G_3." (See *Fig. 21.*)

Different from this is the division of the loads for the shearing forces. From equation:

$$S_m = V_m - H \, tng \, \mu_m = Q - G_1 - H \, tng \, \mu_m \tag{6}$$

follows, that:

"The point under consideration $x_m\, y_m$ forms a part of the *second* division G_2, while the top joint belongs to the third division G_3." (See *Fig. 22.*)

I shall henceforth represent, when necessary, the divisions G_1 G_2 G_3 as shown in (b) *without* always adding the form of the line of thrust (a).

Now S is the increment per unit of length of M. The above rule gives us thus the means on hand *to express correctly the actions of the difference (algebraically) of two moments.* I will show this more clearly yet in expressing S as the difference of two values of M.

Using eq. (I^a), we have:

$$M_m - M_{m-1} = \frac{\zeta'_m - \zeta'_{m-1} - (y_m - y_{m-1})}{2f} \left[(G_1 g_1)_m - (G_1 g_1)_{m-1} \right] +$$

$$+ \left[(G_2)_m - (G_2)_{m-1} \right] \left\{ (x_m - x_{m-1}) - \left[(g_2)_m - (g_2)_{m-1} \right] \times \right.$$

$$\left. \times \frac{\zeta_m - \zeta_{m-1} + (y_m - y_{m-1})}{2f} \right\} + \left[G_3 (l - g_3)_m - G_3 (l - g_3)_{m-1} \right] \times$$

$$\times \left\{ \frac{\zeta_m - \zeta_{m-1} - (y_m - y_{m-1})}{2f} \right\}$$

dividing by $\varDelta x_m$ and writing, see *Fig. 23.*

$$\frac{\zeta'_m - \zeta'_{m-1}}{\varDelta x_m} = - \, tng \, \mu_f;$$

$$\frac{\zeta_m - \zeta_{m-1}}{\varDelta x_m} = tng \, \mu_f$$

$$\frac{y_m - y_{m-1}}{\varDelta x_m} = tng \, \mu_m$$

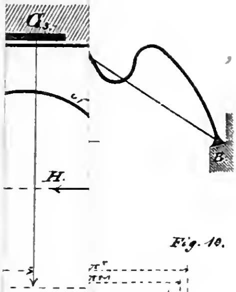
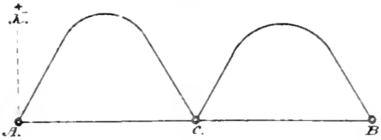


Fig. 5.



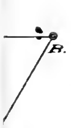


Fig. 10.

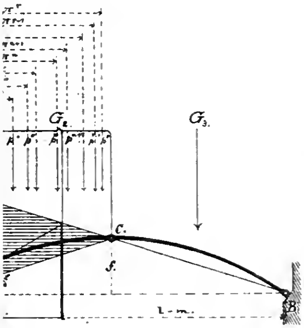


Fig. 11.

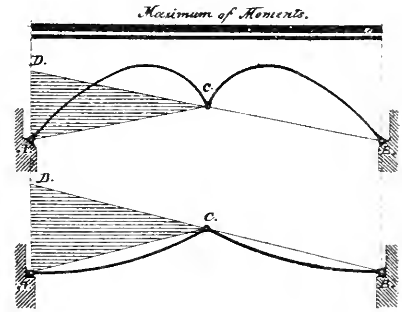
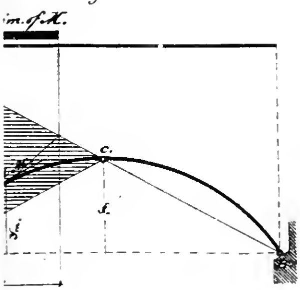


Fig. 16.



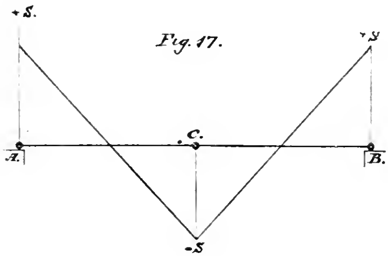


Fig. 17.

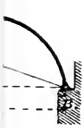


Fig. 22.

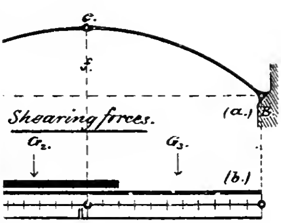
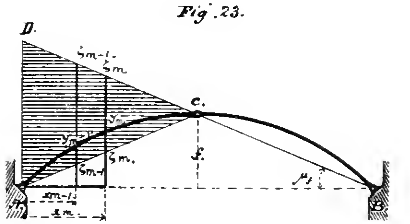


Fig. 23.



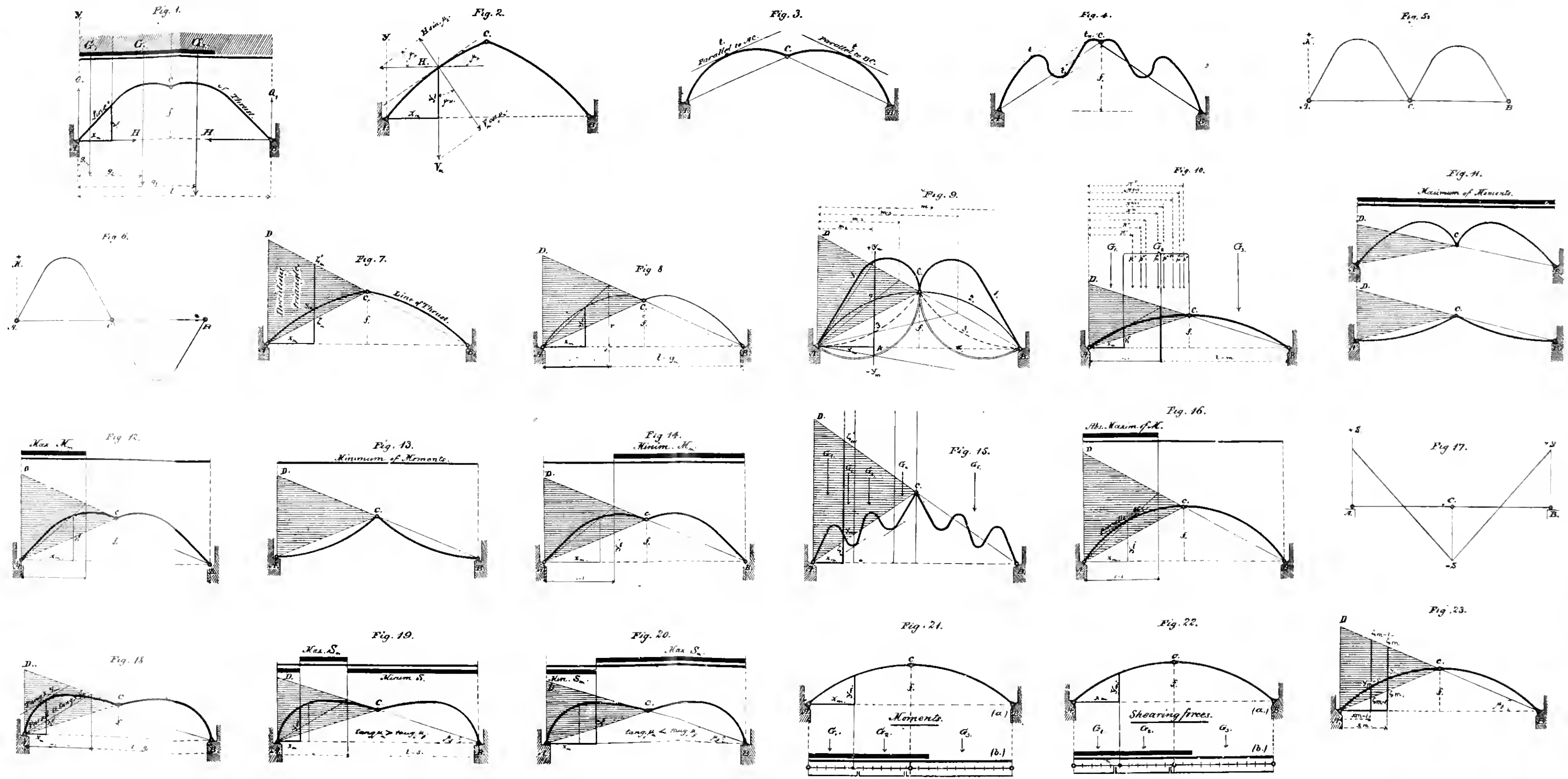


Fig. 1.
Line of Thrust
Fig. 2.
Fig. 3.
Parallel to AC.
Parallel to BC.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Directing triangle
Line of Thrust.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Maximum of Moments.
Fig. 12.
Max. M
Fig. 13.
Minimum of Moments.
Fig. 14.
Minim. M
Fig. 15.
Fig. 16.
Abs. Maxim. of M.
Fig. 17.
Fig. 18.
Fig. 19.
Max. S
Minim. S.
Fig. 20.
Min. S
Max S
Fig. 21.
Moments.
Fig. 22.
Shearing forces.
Fig. 23.

this equation gives:

$$\frac{M_m - M_{m-1}}{\Delta x_m} = S_m = -\frac{tng\,\mu_f + tng\,\mu_m}{2f}\left[(G_1\,g_1)_m - (G_1\,g_1)_{m-1}\right] +$$

$$+\left[(G_2)_m - (G_2)_{m-1}\right]\left|1 - \left[(g_2)_m - (g_2)_{m-1}\right]\frac{tng\,\mu_f + tng\,\mu_m}{2f}\right| +$$

$$+\left[G_3\,(l - g_3)_m - G_3\,(l - g_3)_{m-1}\right]\frac{tng\,\mu_f - tng\,\mu_m}{2f}$$

In comparing the last equation, with eq. (II^a), we see that $a\ b\ c$ of course have the same values, as they express simply geometrical properties, and are completely independent of the way of loading, but the action of $G_1\ G_2\ G_3$ appears as the difference of the two values of M, and the correct action of this difference could not be defined, *without* the above rule for shearing forces.

The above rule for defining the correct division of $G_1\ G_2\ G_3$ of the shearing forces is thus of the greatest importance. It gives, *as long as we add or deduct only the values of two moments, the correct action, or the correct division of* $G_1\ G_2\ G_3$ *in the girder*, in transforming the value of S into that of M, or *vice versa*, and allows in this way the substitution of one force for the other.

Beside the division of $G_1\ G_2\ G_3$, the correct position of the loads making the moments or the shearing forces to maxima or minima, depends also upon the greatest value of $G_1\ G_2\ G_3$ possible. But as this point can much better be explained with the expressions of the internal forces, I will leave it until these expressions are developed, and turn now to the development of the equations of the internal forces.

(*To be continued.*)

CORRESPONDENCE.

THE IMPROVEMENT OF SABINE PASS.

The Committee on Publications of the FRANKLIN INSTITUTE.

WASHINGTON, D. C., April 9, 1888.

Gentlemen :—I see on perusing your April number that Prof. Haupt in his discussion on "Jetties for Improving Estuaries" has made use of some mis-information in reference to the Sabine Pass, Louisiana and Texas. He states that the west jetty (which was the one first commenced, neither being as yet *built*) made a shoal on its east side. Now the fact is, that the partially-constructed west jetty had in 1885, the date he mentions in his article, caused quite extensive deepening and scour on its east side; the curve of eighteen feet depth inside the bar had moved outward 600 feet, and that on the outside of the bar had moved shoreward from 200 to 1,100 feet, so that the distance between this curve of depth on the inside and on the outside had decreased 1,600 feet; the curve of nine feet depth on the inner side of the bar had moved outward 2,150 feet, and that on the outer side had changed but little; the channel of six feet depth had increased in least width from 550 feet, according to the 1881 survey, to 2,300 feet at that time, 1885. All these facts were exhibited on the page of the official report under Prof. Haupt's eye when he wrote.

On this same page of the official report, it was shown that the nine-feet curve to the *westward* of the jetty had advanced between 700 and 1,100 feet, and the six-feet curve inside the *Clifton* (a war wreck) had been obliterated by deposits, while outside that wreck this curve had advanced 2,700 feet. The fact is that the west jetty had caused immense shoaling on *its western side*, as could be seen by the 1884 and the 1885 reports.

Very respectfully your obedient servant,

THOMAS TURTLE, *Captain of Engineers.*

To the Committee on Publications of the FRANKLIN INSTITUTE JOURNAL:

Gentlemen :—In reply to the above criticism I beg leave to submit that from the manner in which the criticism is made, and especially in the allusion to the exhibit of facts "under my eye when I wrote," it would seem to question the veracity of my statements. I respectfully submit, therefore, the following, as the paragraph alluded to by Capt. Turtle. I say in the paper on jetties: "At Sabine Pass, estimated to cost $3,177,606.50, the *west* jetty was built first and made a shoal on its east side, and in 1885 the crest of the bar had been moved seaward 1,900 feet, and it is said 'it is perhaps impossible to

decide as to the amount of influence the work done has had upon the depth of water across the bar.'"

All of the above are facts as gleaned from the official report of the Chief of Engineers, and they are the important facts in this case. Capt. Turtle appears to attach great importance to the movement of the contour lines and the enlargement of the inner basin, which is merely a natural consequence of the obstruction produced by the jetties and contraction of the ebb, whereby a reaction is produced, which tends to deepen the channel in the Pass and push the bar further seaward, as stated by the assistant in charge of the surveys.

Permit me to quote a few extracts from the history of this improvement: "In 1878, a channel twelve feet deep was dredged across the bar; another was dredged in 1880; both soon refilled." * * * "The work was commenced in 1883 (January 1), and in 177 working days in that year 118,552 cubic yards of jetty were laid, embracing a total length of 16,074 feet of the foundation of the west jetty; 6,146 feet of which, from the shore end, was built nearly or quite up to the level of mean high water." Work was then stopped in consequence of the expenditure of the appropriation until after July 5, 1884, "when a survey and examination was made by and under the direction of Capt. Turtle," who made a report suggesting "a new line differing somewhat from the originally proposed line of the east jetty."

I think, therefore, that there is no doubt but that the *west* jetty was built first (I did not say completed). It was in existence for a distance of over three miles from shore (over one mile reaching nearly to mean high water) for over a year before the east jetty was commenced as shown from the following: "Work was commenced on the east jetty in March, 1885, and on June 30, 1885, the foundation course was laid for a distance of 10,200 feet from shore and 8,825 feet of this jetty extending out from the shore was built up to mean high water level." "The contractors will probably finish their work in August of this year (1885.") * * * "The portions of the jetties thus far built have produced no material changes in the depth of water on the bar, nor at this stage of the work were any decidedly favorable changes to be expected." * * * "When the two jetties are built up high to the outer crest of the bar, then a scour may reasonably be looked for; should the expected scour not occur, then resort would be had to the dredge." These extracts are from the report of Major Heuer.

Again, the figures stated in Capt. Turtle's letter are those taken from the report of Assistant Engineer Raymond, and based upon a survey made in August, 1884, or prior to the beginning of work upon the east jetty, so that the changes produced were those due to the west jetty only, and in stating what these changes were, Mr. Raymond says:

"The line of deepest water over the bar has moved somewhat to the eastward by the formation of a shoal opposite the *Clifton*,* and extending from the jetty 1,000 feet east, upon which the depth has decreased from 0·6 to 1·3 feet since 1881."

* Which is on the line of the west jetty.—L. M. H.

The curves referred to, as drawn in red upon the comparative chart submitted, are not shown in the report, so that the map gives no very definite information as to relative changes.

He adds: "The extent and position of the sand deposit would seem to leave but little doubt as to its origin. As shown upon the chart by the dotted area,* it lies almost entirely upon the east side of the west jetty, the small deposit to the westward having been probably carried over the top of the jetty. The main deposit extends to the eastward to a point nearly on the prolongation of the six-foot curve on the east side. Its width is greatest near the jetty and diminishes as it extends to the eastward until it finally disappears."

Mr. Raymond also adds in concluding his report:

"The strong currents due to the extreme high water of last spring having deepened the channel above the jetty, where the work cannot be claimed to have had any effect, it is perhaps impossible to decide as to the amount of influence the work done has had upon the depth of water across the bar. The greatly increased width of the nine-foot channel and its prolongation so far down stream might fairly be attributed to some extent to the narrower water way produced by the jetty." * * * "The crest of the bar, as determined by a line joining the points of the six-foot curve nearest together, has advanced into the Gulf 1,900 feet."

The changes then above the bar, according to the Assistant Engineer, were produced by extreme high water and the contraction of the ebb stream, producing a reaction in the throat of the Pass, and the beneficial results in deepening the water, are incapable of being determined. The crest has also moved gulfward, as I have stated, unless the reports themselves are misleading.

As to the "immense shoaling on *its western side*," it is easily explained. The jetty was submerged at that date for a length of over two (2) miles, the sand carried westward by the "flood component" as well as that coming down the Pass, was rolled over the jetty and deposited in the groin formed by the jetty and shore which was its natural depository. It built its own ramp to the eastward of the jetty and was then readily carried over it by the flood. If a survey were made to-day it would doubtless show a similar slope to eastward of the east jetty over which the sand is prevented from climbing only by its being extended to or above high water, but it will ultimately creep around the end as the angle fills up.

I have respectfully to submit, therefore, that the extracts contained in my paper on "Jetties for Improving Estuaries" do not misstate or misrepresent the facts in the case, unless I read them incorrectly; if otherwise, I should be pleased to make the necessary acknowledgements.

Very respectfully, your obedient servant,

LEWIS M. HAUPT.

UNIVERSITY OF PENNSYLVANIA,

PHILADELPHIA, *April 21, 1888.*

* This is not shown in the reproduced chart accompanying reports in my possession.—L. M. H.

DOWNWARD-DRAUGHT FURNACES.

The JOURNAL OF THE FRANKLIN INSTITUTE for February, 1888, contains an article by Mr. Francis E. Galloupe, purporting to be a supplement to the investigation of Lozano and Erben upon downward-draught furnaces published in the JOURNAL for November and December, 1887.

The article is mainly an attempt to discredit the record of the experiments made at 94 Liberty Street, New York, by trying to show from our account of the experiments that some points necessary to the carrying out of the details of the tests in a proper manner seem to have been overlooked; and of a report of a ten-hour boiler test in East Somerville, Mass., totally irrelevant to the investigation it assumes to supplement.

Mr. Galloupe finds fault on the following points:

(1) Large percentages of refuse from the coal.

(2) Percentages of unburned coal, which must have parted with some of its calorific power if put in the furnace at all, different in the two trials.

(3) Variations of water level.

(4) Absence of correction for one-half inch too high water-level in the boiler at the end of the second test.

I shall briefly take up those points in their order.

(1) The total weight of refuse per pound of coal put into the furnace was in the first test ·271,066 pound, and in the second test ·269,230 pound. As long as this was practically the same, it does not make a particle of difference in the conclusions to be derived from the comparison of the results of those competitive tests, whether the percentage was large or small.

(2) The way to get the approximate weight of that part of the coal, other than ashes, which escaped unburned, is to subtract from the total weight of the refuse the weight of real ashes in the coal as determined by analysis. Thus, the total weight of unburned carbon per pound of coal put into the furnace is seen to have been ·172,566 pounds in the first test, and ·170,730 in the second, the discrimination complained of being well nigh infinitesimal, and certainly within the limits of the unavoidable errors of observation. Mr. Galloupe used the wrong figures, taking for unburned coal only that which was picked from the ashes.

(3) The height of the water in the glass gauge was, as reported:

	Test with Ordinary Grate. Inches.	*Test with Downward-Draught Attachment, Inches.*
Lowest,	1	1·5
Highest,	4	4·5
Mean during the tests,	2·84	3·23

a difference of ·39 inch in the mean height.

(4). One-half inch of water in a boiler 14 feet long, 5 feet in diameter, amounts to less than 182 pounds; 182 pounds of water heated from the temperature of the feed to the steam temperature at which the trial was ended, means 31,122 British thermal units, to impart which at the efficiency found, would require only 3·74 pounds of the coal; or, in other words, the correction desired would be only about one per 1,000 of the coal used in the test. On the other hand, whereas the first test was begun and ended with steam of

precisely sixty pounds pressure, the second test was begun at sixty pounds and ended at forty-eight pounds, a drop of temperature on the total weight of the contents of the boiler, etc., of about 13° F., correction for which unavoidable fact would be in the opposite way, and somewhat greater. We were not censured for having likewise deliberately omitted this correction against the device.

Mr. Galloupe says, also, that "the admission that the water-level was left one-half inch higher at the end of the second test 'through inadvertency,' makes the feed-water record inaccurate." Singular, indeed! Nevertheless, anyone can see that the accuracy of the weight of the feed water has nothing to do with the inadvertency of the man in charge of the feed pump, or with the admission.

The superiority of the water-tube grate in regard to burning the coal up cleaner than the ordinary grate, was represented by 6·78 pounds in 3,692 pounds of coal used. We made no mention of it, because it was too small a quantity of its kind to be mentioned at all.

Really, if Mr. Galloupe can obtain from all his points, any quantity the commercial value of which is appreciable, he should compute and exhibit it.

418 W. Fifty-seventh Street, Carlos A. Lozano, M.E.
New York, *March, 1888.*

The LIMITING DIAMETERS of DESCRIBING CIRCLES for the TEETH of ANNULAR WHEELS.

In a note relating to "the Limiting Diameters of Describing Circles for Teeth of Annular Wheels," in your issue of April, 1888, Mr. Albert K. Mansfield states that in my "Treatise on Kinematics," (1883,) I "practically claim to be the original discoverer of the law of kinematics bearing on that point" —immediately adding that he had published a demonstration of that law in your issue of January, 1877.

Mr. Mansfield apparently uses the words "original discoverer" as synonymous with "first discoverer;" whence some of your readers may have received an erroneous impression, as reference to my preface will show that I did not positively claim the credit of priority, which, in mathematical matters, it is always unsafe to do, because identical results are very often, as in this instance, independently reached by different persons.

Mr. Mansfield further says: "It would seem, in the absence of evidence to the contrary, that he was not aware of your previous publication of the matter."

Allow me to assure your readers, since he does not, that this supposition is correct—the absence of evidence is accounted for by its non-existence.

I am perfectly willing to admit that Mr. Mansfield preceded me in point of time; but I did not know of his investigation until more than four years after the publication of my treatise.

Of all which Mr. Mansfield was informed, some time previously to the appearance of his note. C. W. MacCord.

Stevens Institute of Technology,
April 16, 1888.

BOOK NOTICES.

THERMO-DYNAMICS. De Volson Wood, C.E., M.A. New York: Burr Printing House, 1887. 12mo. pp. x. 234.

This little work, which was written by Prof. Wood for his own use in the class room, divides the general treatment of the subject into four parts, namely, general principles, perfect gases, imperfect gases, and heat engines, and also contains an appendix on the luminiferous æther, and one on the second law of thermo-dynamics.

The attempt of Prof. Wood to put into a convenient shape this subject for class room use is to be commended, but it is difficult to see that he has succeeded.

As in the examination questions after Chapter I, he says that some of these questions require knowledge outside of the text, it would appear that the ground had not been covered sufficiently to make it a good text-book. While the intricacies of the theory of thermo-dynamics are of necessity part of the education of a scientist or professor of dynamics, it hardly seems necessary to go into the matter to the same extent for students, and a statement and proof of the fundamental theories and their practical application seems to be the more desirable course. As the majority of students in after life could use the practical applications if they were fully and plainly set forth, the general knowledge obtained in a course of instruction, as above indicated, would point the way for the very few men who desire a greater knowledge of the subject.

The meaning of many terms in the work are not as distinctly stated as one might wish. The distinction between a reversible and a non-reversible cycle, as made in Art. 32, is entirely unnecessary, and according to an equally good authority (Röntgen-Du Bois), is incorrect. In Art. 26 two examples are given of re-entrant curves, and unless the author means closed curves it is hard to tell what his "re-entrant" means. While the articles on the mechanical equivalent of heat is interesting it is misleading, as the table furnished by him would lead a student to infer that the mechanical equivalent varied with the temperature. The graphical method of illustrating the amount of heat absorbed according to any law is constantly used throughout the work and tends to elucidate what to the student might otherwise seem rather obscure.

The ammonia engine (refrigerating) is dismissed with a paragraph which gives no information on the subject, while the air compressor receives about the same treatment.

The clearness of the treatment of the subject of specific heat might well have been used in other parts of the work.

The treatment of the thermo-dynamic function, Art. 97*a*, is such that one turns for relief to Rankine (Art. 244, *Steam Engine*) and if that article had been transferred bodily, one article, at least, would be much clearer. A page and a half is allotted to the condenser and no attempt is made to explain what actually takes place in it.

One of the interesting parts of the book is that which treats of cutting-off in steam engines, and the solution of the problem of the most economical point of cut-off is interesting, although incorrect.

In equation 190, page 183, we have an expression for the work done for unit of cost ($1) of steam and evidently a maximum value with reference to the ratio of expansion as a variable will give the most economical point of cut-off at which to run the engine. Looking back at the equations from which 190 is deduced, we find, as follows:

$$A\,l\,n = r\,v\,W \quad (188)$$

in which

A = area of the piston in square feet;
l = length of stroke in feet;
n = the number of times the engine takes steam in unity of time;
r = the ratio of expansion;
v = the volume of unity of weight (one pound) of steam at the pressure p_1 (= the initial absolute pressure in the cylinder per square foot);

and

W = weight of steam used by the engine in unity of time—one hour.

With the above statement of the meaning of the terms in the equation, it is evident that it is incorrect, as it is a fact well known to Prof. Wood that the weight of steam used in any engine is in excess of that necessary to just fill the volume passed through by the piston, and this fact is recognized on page 188, where he allows thirty per cent. for condensation; on page 198, where it is shown that the amount of condensation varied with the point of cut-off, and in many other cases. And as this equation is one which is used in determining the proper point of cut-off, it is clear that any point of cut-off, derived from any equation in which this enters cannot be the most economical, although "forty students" obtained results which differed but slightly. And it might be well to note here that any criterion which does not take into account the fact that the amount of condensation varies with the point of cut-off, as is plainly set forth in the results given on page 198, omits what is often a very important item in an investigation of this kind, and is of no account in determining the most economical point of cut-off. H. W. S.

A Manual of Steam Boilers, their Design, Construction and Operation. R. H. Thurston, M.A., Doc. Eng. New York: John Wiley & Sons, 1888. pp. xvi–671.

This latest work of Prof. Thurston's, as the title page announces, is for technical schools and engineers, and covers the ground stated in its title fully. Briefly, the different subjects treated of are history and classification, materials, fuels, heat, thermo-dynamics, designing, care, trials and efficiency, and explosions.

The book, as the author says, is a "larger book than could be profitably used in the average technical school," and there seems to be no reason why it could not have been made much smaller and have still covered the ground

as fully as it at present does. It has been freely padded, and the omission of many of the paragraphs, especially in the first half of the book, would have brough it into such a shape that it could have been used very well in the "average technical school." For instance, on page 253, the first six lines read: "The properties of water, as noted by the senses, are familiar to all. It occurs universally distributed throughout the world, in earth, air and sea, in its three forms, ice, water and vapor, and in its most familiar form covers three-fourths of the surface of the globe. As ice and snow it permanently covers the Arctic region and the top of lofty mountains, etc." Compilations of facts of this sort are of but little use to either a student of the "average technical school" or to an engineer, and the omission of many other passages of the same sort would have made a more useful work it. To anyone not having a copy of Prof. Thurston's previous works, the treatment of materials is all that can be desired. The subjects of heat and thermo-dynamics are treated more fully than necessary in a book of this kind. There is the same excess of words here that has already been referred to, and it is simply a waste of time to read, even on the authority of Prof. Thurston, that water is to be found in the sea, etc.

That part of the work between pages 300 and 538 treating of the design, care and testing of steam boilers, is the only part of the work which deserves a place in an engineer's library. This is by far the best series of articles on how to design a boiler, and the reasons for so doing, that has ever been presented in book form. The data given have been put into such a shape that they can be instantly used, and for this reason they are invaluable to the engineer who is not a specialist in boilers.

The publication here of the method of testing adopted by the American Society of Mechanical Engineers will tend to promote uniformity of work among those not members of the Society. The apparatus for testing boilers described, although perhaps not the best attainable for the purpose, will enable one to make accurate and satisfactory tests.

The latter part of the book, which is devoted to steam-boiler explosions, could have been nearly all omitted without injuring the character of the work.

An inspection of the engravings alone will show that while many of them might serve very well for newspaper cuts, in a volume of this sort they simply take up space. H. W. S.

USE OF BELTING FOR TRANSMISSION OF POWER. By John H. Cooper, M.E. Third Edition. Phila.: Edw. Meeks: London, E. & F. N. Spon, 1888.

It is a rare thing that a practical engineer of large experience makes a book upon the subject with which he is most fully conversant, and when made such books are too often records of mere conclusions and inferences rather than of facts; faults from which this treatise is exempt.

This work submits concisely and clearly, well-illustrated descriptions of the many devices and arrangements under which belting is used, with a careful recital of all of the conditions involved in each case, and such rules and tabulated information as naturally result from facts and tests described.

With this there is a careful compilation of pertinent matter from the works of others on the subject, in every instance duly accredited, and the whole is thoroughly well indexed.

The manner in which the earlier editions of this work were appreciated by practical men is a strong endorsement by the most competent critics upon the subject; the present edition contains much additional information and is compiled with the same conscientious care that has secured the confidence of the engineering public in all of this author's works. The book is simply invaluable as the best on the subject. S. L. W.

SCIENTIFIC NOTES AND COMMENTS.

TECHNOLOGY.

A NEW PROCESS OF PROTECTING IRON EFFECTUALLY AGAINST CORROSION.—For a period of more than ten years experiments have been made under the auspices of the Hydrogen Company of the United States to discover a simple, economical and practical method of protecting iron and steel from all ordinary corrosive influences. A large number of patents were secured and about $100,000 expended in the erection of plants at Washington, D.C., Newburg-on-the-Hudson and New York, and some of the results were of the most satisfactory character. Iron that had been treated by the processes referred to effectually resisted the action of nitro-muriatic acid and other severe tests to which it was subjected, while untreated iron was immediately attacked by the acids and quickly destroyed.

But although many of the specimens thus treated gave very satisfactory results, others proved defective, and it became apparent to the contributors to the funds that the exact conditions as regards temperature, quality and quantity of material employed, and duration of treatment had not been so accurately determined that results could be duplicated with unerring certainty; an essential condition without which no process could ever be made a commercial success.

This explanation has been considered necessary to account for the fact that an industry which promised results of such extraordinary value to the public and to the parties financially interested should have been allowed to linger until the greater portion of the life of the original patents had expired.

But persistency has at last been rewarded with success. The company succeeded in securing the services of a thoroughly practical and scientific engineer, chemist and metallurgist, Dr. Geo. W. Gesner, who was enabled to discern the defects of former treatments and to remedy them successfully by new apparatus and processes, which have recently been patented, so that while the old patents are still held by the company, they have to a great extent been superseded by more recent issues under which operations now are and will hereafter be conducted.

The former treatment consisted in placing the articles to be operated upon in a close chamber, similar to a gas retort, and when heated to a temperature

of about 1,200° F., steam superheated in a separate furnace was introduced, followed by naphtha or other hydrocarbon vapor.

The results, as previously stated, were not always uniform, and when satisfactory, could not be duplicated under former management with certainty as to the result.

All this is now changed, and the results are so uniform and certain, that with a few hours of instruction in the manipulation of the apparatus an ordinary laborer, with no technical education and with average intelligence, can secure results with entire uniformity.

Dr. Gesner soon discerned that one of the chief defects in the former treatment arose from the fact that the steam superheated in a separate furnace and conducted by pipes into the retort was invariably cooled to the extent of several hundred degrees before admission and came in contact with the heated iron at a much lower temperature.

To remedy this defect and insure absolute uniformity of temperature between the iron and the superheated steam at the instant of contact, a peculiar but very simple form of superheater was devised and inserted in the retort itself. The result was entirely satisfactory, and after a number of experiments by him to determine the conditions necessary to insure the best treatment, the works were turned over to an employé who has since operated them with uniform results.

The plant now in operation is located at East Port Chester, near the extensive foundry of Abendroth Brothers, and consists of twelve vertical retorts with a capacity for the treatment of about twenty tons per day of the Gesner sanitary soil pipe. The time required for each charge is about two hours.

THE PROCESS.

After the pipes have been lowered into the retorts by means of a traveller, the retorts are closed for about fifteen minutes until the contents are heated to the proper temperature. Steam from a boiler at sixty pounds pressure is then introduced into the superheater, which it traverses and from which it escapes at the temperature of the iron upon which it acts for about one hour. A measured quantity of some hydrocarbon is then admitted with a jet of steam, followed again by a fixing bath of superheated steam, which completes the process.

The most extraordinary feature of the operation is that, as Prof. Gesner positively asserts, there is no pressure in the retort and no free explosive gases. The water seals attached to the retorts show only slight oscillations, but not an inch of pressure, and when the covers are removed and air admitted, there is no explosion, as there always is when free hydrogen or carbonic oxide are present, and as there always was before Prof. Gesner took charge.

The absence of pressure and of explosive gases is a proof that all the operations have been so nicely regulated as regards material used, quantity and time of application, that a perfect absorption and union of the carbon, oxygen and hydrogen with the iron has been effected.

The protection thus afforded to the iron is not a mere coating, like paint,

but an actual conversion, to a greater or less depth, into a new material, just as in the process of case-hardening, iron is converted into steel. When properly treated, this material does not seem to be detachable by pounding, bending, hammering, rolling or heating. The pipes treated at Port Chester have been immersed in baths of dilute sulphuric acid and exposed to the salt air for weeks without change, while untreated pipes were quickly covered with red oxide or with sulphate of iron.

The exact chemical composition of the material produced by this treatment has not been reported upon by Prof. Gesner, but it is probably a carbide, hydride and superoxide of iron. This would seem to be a necessary result, if, as is stated, the retorts when opened contain no free gases, neither hydrogen, oxygen nor carbonic oxide. As these gases are necessarily formed, their disappearance can only be explained on the theory that they have combined with the iron forming the three compounds of superoxide, plumbago and the alloy of hydrogen and iron, for which Prof. Gesner has proposed the name of Hydron.

The plant now in operation at Port Chester has been designed simply for cast-iron soil pipe, but Prof. Gesner is preparing plans for a more extensive plant for the treatment of wrought iron and steel, to be erected at South Brooklyn.

In the application of this process each specialty will require a plant adapted to it, and a series of experiments to determine the exact conditions as to temperature, quantity, kind, duration, etc., to secure the best results, after which they can be duplicated indefinitely with any ordinary intelligence.

The question is often asked: What is the effect of this treatment upon the tensile strength of the material? This can only be answered by direct tests, but if the new material should not possess the tensile strength of the untreated iron, as in wires or rods, compensation can be secured by a slight increase in diameter. It is certain that in some specimens the treatment has increased the toughness and strength by the annealing process to which the material is subjected. Sheet iron of poor quality, that would break by bending, has been rendered tough and pliable.

The cost of the process is said to be about one-fourth of that of galvanizing, while the durability under similar conditions promises to be greatly extended. H. Haupt.

On the Laboratory Application of Raoult's Method for the Determination of Molecular Weights.—K. Auwers (*Berliner Berichte*, **21**, 701). Raoult has shown that the lowering of the freezing point of a liquid occasioned by the solution of any substance is a function of the molecular weight of that substance, and has deduced formulæ by which molecular weights may be calculated from observed lowering of the freezing points. The method has been experimentally verified with several solvents by Blagden (*Phil. Trans.*, **58**, 277), Coppet (*Pogg. Ann.*, **114**, 63; **116**, 55; **145**, 599), and again by Raoult (*Ann. Chim. Phys.*, **4**, **23**, 366; **25**, 502; **26**, 98; **5**, **20**, 217; **28**, 133; **6**, **2**, 66, 93, 99, 115; **4**, 401; **8**, 289, 317).

If C be the lowering of the freezing point occasioned by the solution of P

grammes of substance in L grammes of the selected liquid, and A the depression occasioned by one gramme of the substance in 100 grammes of the liquid,

$$A = \frac{C \,.\, L}{P \,.\, 100}$$

The value A is named by Raoult the coefficient of depression for the substance and liquid, and its product when multiplied by the molecular weight M of the dissolved substance, yields a value $M \,.\, A = T$, which he calls the "molecular depression" of the substance. The value of A varies with the nature of the substance, and like that of T, with the nature of the solvent, but when the same solvent is employed, T remains sensibly constant for large classes of substances of analogous chemical constitution. In other words, substances of similar chemical constitution exert the same molecular depression.

The law has been still further investigated by Raoult, who shows that if the calculation be made for the depression T_1, caused by the solution of one molecule of the substance in 100 molecules M_1 of the solvent, the value

$$T_1 = \frac{M}{M_1} A = \frac{T}{M_1}$$

is not only constant so long as T remains constant, but that it remains sensibly the same no matter what solvents be employed. Thus, if t_1, t_2, t_3 be the molecular depressions of liquids whose molecular weights are m_1, m_2, m_3,

$$\frac{t_1}{m_1} = \frac{t_2}{m_2} = \frac{t_3}{m_3} = T_1 = \text{constant.}$$

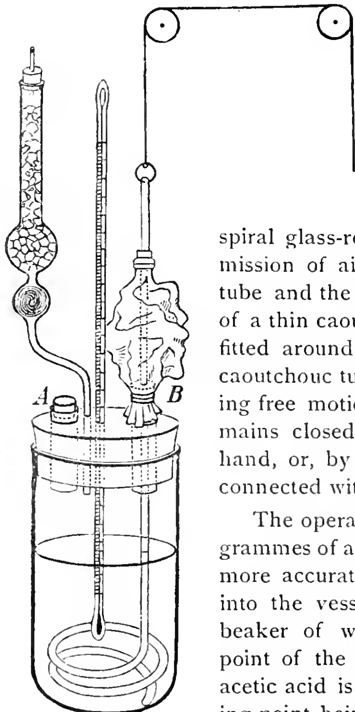
The value of this constant, according to the experiments of Raoult, varies between 0°·59 and 0°·65, and the mean is 0°·63, and the law may be expressed as follows: If one molecule of any substance be dissolved in 100 molecules of any chosen solvent, the freezing point of the latter will be lowered 0·°63. Raoult names this the general law of congelation.

The law holds good for temperatures between 0° and 80°, the freezing points of the solvents used by Raoult lying within these limits. It does not appear to apply in the case of water, with which the value of T_1 varies between 0°·92 and 1°·27 for carbon compounds, and is different for each class of salts, a fact probably depending on a not fully understood chemical action.

The liquid best adapted for the determinations is crystallizable acetic acid, and even when the substance under experiment is hygroscopic it is not necessary that the acid shall be perfectly dry, for while the result of the first experiment may be erroneous, the substance already introduced will have taken any small quantity of water present, and the introduction of a second and a third quantity will produce constant results. The molecular depression of acetic acid is about 39.

It must be well understood that the method does not yield absolute results; it cannot be used as a substitute for the determination of vapor densities, but it will prove of immense service in cases where the determination of vapor densities is impracticable or impossible.

The apparatus required for the experiments is quite simple. A beaker, 4·5 or 5 cm. in diameter and 13–16 cm. high, is fitted with a caoutchouc stopper pierced with four holes. Through the central hole passes a good thermometer, graduated, say, from 0° to 50° in one-tenth degrees, and the bulb of the thermometer should be in the middle of the liquid. Behind the thermometer a calcium chloride tube is adapted to one of the openings for the drying of the air, which enters as the vessel is cooled. Through the third opening passes a short, wide tube, which is closed by a cork that is only removed to drop in a crystal of acetic acid, in order to start the congelation. The other opening is also fitted with a short tube through which passes, without friction, the stem of a spiral glass-rod agitator, and that there may be no admission of air in the space between the walls of the tube and the rod, the latter is passed through the wall of a thin caoutchouc balloon, the opening of which is fitted around the extremity of the tube; a very thin caoutchouc tube will answer the same purpose, allowing free motion up and down, while the opening remains closed. The agitator may be moved by the hand, or, by means of a cord and pulleys, may be connected with a small water motor.



The operation is conducted as follows: About 100 grammes of acetic acid—the weight need not be known more accurately than to decigrammes—are introduced into the vessel, and the latter is placed in a large beaker of water, cooled 1° or 2° below the melting point of the acetic acid; that is, to about 14°. The acetic acid is then cooled to ½° or ¼° below its freezing point, being constantly stirred by aid of the agitator, and a crystal of acetic acid is then dropped into the liquid. The mercury then falls two- or three-tenths of a degree, but soon begins to rise, at first rapidly, then slowly; in a short time a maximum is attained, after which the temperature slowly falls. The maximum temperature is read to the $\frac{1}{100}$ths of a degree by the aid of a magnifying glass, and this temperature is accepted by Raoult as the true freezing point. The apparatus is then removed from the beaker of water, and placed on a water bath, care being taken that the steam does not touch it. As soon as the acetic acid is perfectly liquified, a second determination of its freezing point is made in the same manner as the first; the result of the second experiment is 0°·01, 0°·02 or even 0°·03 below that of the first, and a third determination will sometimes show a still further depression of 0°·005. The differences are probably to be explained by the moisture on the walls of

the vessel and in the balloon at the beginning of the experiment, and the substance, whose molecular depression is to be determined, should not be introduced until the freezing point of the acid is constant in two determinations; sometimes two are sufficient—four may be required. As soon as a constant freezing point is indicated, the substance under experiment, accurately weighed to milligrammes, is dropped into the apparatus through the wide tube, and after it has been dissolved by stirring, three determinations of the freezing point are made; the greatest difference between the first and third will be about $0^{\circ}\cdot01$. A second weighed quantity of the substance is then introduced, and three more determinations made, the differences observed in this series being similar to those in the first.

The required time is about ten minutes for each determination; three or four hours will suffice for a series of, say, eleven consecutive determinations with all the manipulations and weighings. W. H. G.

GEOLOGY.

Geological Map of Europe.—Those readers of the Journal who are interested in geography or geology, are notified that the subscription list to the Geological Map of Europe, which the International Geological Congress is to issue shortly, is nearly complete, but twelve more copies remaining to make the century assigned to the United States. As almost all, if not all, the leading institutions of learning and of research in the country are subscribers to this map, it is time for those who desire to avail themselves of the opportunities of securing it, at twenty per cent. less than its market price, and before it is sold to the general public, to send their names in to Dr. Persifor Frazer, Secretary American Committee, 201 South Fifth Street, Philadelphia. The cost of the map to institutions will be $21, and to individuals $26, the difference being the duty, which to the former class is not chargeable. No money contribution is required until the map is issued, which will probably not be before next fall or winter.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, April 18, 1888.*]

Hall of the Institute, Philadelphia, April 18, 1888.

Mr. Jos. M. Wilson, President in the Chair.

Present, 132 members and fourteen visitors.

Additions to membership since last meeting, sixteen.

The Actuary reported the election, by the Board of Managers, at its meeting held Wednesday, April 11, 1888, of the following persons, to serve as Trustees in accordance with Article I, Section 2, of the By-Laws:

Chas. Hare Hutchinson, John T. Morris,
Edward Longstreth, Samuel Sartain,
J. Vaughan Merrick, Wm. Sellers,
Joseph M. Wilson.

The Special Committee to prepare a memorial of the late Prof. JAMES CURTIS BOOTH, presented a report which was accepted and referred for publication.

Mr. WM. B. LE VAN read a paper, entitled "The Decline of Engineering; illustrated by Examples drawn from local Practice," which evoked a free discussion. (Referred for publication.)

Mr. W. N. JENNINGS described and exhibited a number of specimens, illustrating a new method of transferring photographs upon porcelain, tiles, celluloid, silk, etc.

F. E. IVES announced that he had succeeded in applying chlorophyl effectively to gelatine-bromide plates, by flowing with the alcoholic solution, then drying, then soaking in water. A paper giving details of experiments has been referred for publication.

The President announced in suitable terms the death of Mr. JOSEPH ZENTMAYER, distinguished for his skill and ability as an optician and maker of microscopes, and who was for many years an active and valued member of the INSTITUTE. The President appointed the following members as a committee to prepare an appropriate memorial of the deceased: Prof. Henry Morton (*Chm.*), Dr. Chas. M. Cresson, Fred. Graff, Geo. H. Perkins and Prof. Coleman Sellers.

Mr. S. LLOYD WIEGAND offered the following preamble and resolutions, and spoke in favor of their adoption by the meeting viz:

"WHEREAS, The promotion of the useful arts and sciences, under the constitution and laws of the United States, granting letters-patent to inventors, has developed inventions so numerous and diversified in character as to embrace devices in almost, if not every, department of the arts, and a record thereof so voluminous that it is difficult and almost impossible for persons not specially trained to ascertain accurately the state of art in any department of manufactures, under which disadvantages many devices are unnecessarily re-invented, and litigation from conflicting claims often ensues; and,

"WHEREAS, The Commissioner of Patents has again recommended the preparation and publication of properly classified abridgements of letters-patent similar to those issued by the British Patent Office, and has clearly shown that the funds accumulated in the United States Treasury, applicable only to purposes of the patent system, are amply adequate to permit such publication, and has recommended Congress to enact such laws as will enable the preparation and publication of such abridgements to proceed; and,

"WHEREAS, The FRANKLIN INSTITUTE, of the State of Pennsylvania, for the Promotion of the Mechanic Arts realizes the importance of rendering easily accessible to persons practically engaged in arts and manufacture, correct information as to what inventions have been patented in the several departments of their work, and the great utility of such classified abridgements of letters-patent in enabling them to attain such information; therefore,

"*Resolved*, That the FRANKLIN INSTITUTE earnestly recommends and urges upon the representatives in Congress to give operative effect to the recommendation of the Commissioner of Patents by enacting promptly such laws as will secure the preparation, by persons of competent skill and knowledge, of concise and thoroughly indexed classified abridgements of patents for invention, and the publication thereof and the placing of such publications on sale at moderate charges, and accessible to the public in libraries for the better diffusion of knowledge on such subjects."

Adopted.

The President was authorized to call a special meeting to be devoted to an exhibition of the operation and capabilities of the improved phonograph devised by Mr. Thos. A. Edison.

Adjourned. WM. H. WAHL, *Secretary*.

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THE GRAMOPHONE: ETCHING THE HUMAN VOICE.

BY EMILE B RLINER.

[*A paper read at the Stated Meeting of the* FRANKLIN INSTITUTE, *May 16, 1888.*]

JOS. M. WILSON, President, in the chair.

THE PRESIDENT introduced MR. BRELINER, who spoke as follows:

MEMBERS OF THE FRANKLIN INSTITUTE, LADIES AND GENTLEMEN:—The last year in the first century of the history of the United States was a remarkable one in the history of science.

There appeared about that period something in the drift of scientific discussions, which, even to the mind of an observant amateur, foretold the coming of important events.

The dispute of Religion *versus* Science was once more at its height; prominent daily papers commenced to issue weekly discussions on scientific topics; series of scientific books in attractive popular form were eagerly bought by the cultured classes; popular lectures on scientific subjects were sure of commanding

enthusiastic audiences; the great works on evolution had just commenced to take root outside of the small circle of logical minds from which they had emanated, and which had fostered them. Scientific periodicals were expectantly scanned for new information, and the minds of both professionals and amateurs were on the *qui vive*.

Add to this the general excitement prevailing on account of the forthcoming centennial celebration with its crowning event, so dear to this nation of inventors, the world's exhibition, and even those who did not at the time experience the effects of an atmosphere pregnant with scientific ozone, can, in their minds, conjure up the pulsating, swaying, and turbulent sea of scientific research of that period. Science evidently was in labor.

The year 1876 came, and when the jubilee was at its very height, and when this great City of Philadelphia was one surging mass of patriots filling the air with the sounds of millions of shouts, a still small voice, hardly audible, and coming from a little disk of iron fastened to the centre of a membrane, whispered into the ear of one of the judges at the exhibition, and one of the greatest of living scientists, the tidings that a new revelation had descended upon mankind, and that the winged and fiery messenger of heaven's clouds had been harnessed to that delicate, tremorous, and yet so potent form of energy, called the Human Voice.

The speaking telephone had been born.

The stimulus which this event gave to science can best be measured by the enormous advance made since, especially in that now most prominent branch, electricity, and I will show further on how, immediately following it, our sister republic across the ocean answered the magic touch by the conception of another invention, the scope of which cannot to-day be measured yet, and which only just now is starting on its career of usefulness among the practical arts.

In order to show the influence which these two inventions had upon each other, and how their respective development came about in parallel steps, permit me, before entering upon the new methods which I am to bring before you to-night, to pass in rapid review on the principal events in the history of the

transmission of speech electrically, and of recording and reproducing the same mechanically.

In 1854, Charles Bourseuil, with more than usual boldness, advanced the idea that two diaphragms, one operating an electric contact, and the other under the influence of an electro-magnet, might be employed for transmitting speech over telegraphic distances. "Speak against one diaphragm," he said, "and let each vibration break or make the electric contact, and the electric pulsations thereby produced will set the other diaphragm vibrating, and the latter ought then to reproduce the transmitted sound." Outside of the fallacy which his theory contained in the assumption of breaking the contact, instead of merely modifying the same, Bourseuil's paper, in speaking of the diaphragm, laid stress upon stating that "if one could be invented so movable and flexible as to answer to all the undulations of sound." He evidently desired extreme flexibility, and diaphragms constructed on that principle proved fatal to the efforts of many subsequent experimenters; even at first to Mr. Bell, who, like Bourseuil, borrowed the idea from the flexible *tympanum membrani* of the human ear, and who overlooked the important modifications which the vibrations undergo, before reaching the auditory nerve, by the series of muscular hinges in which the various bony accessories of the ear are mounted, and which act as elastic dampers against the *tympanum membrani.*

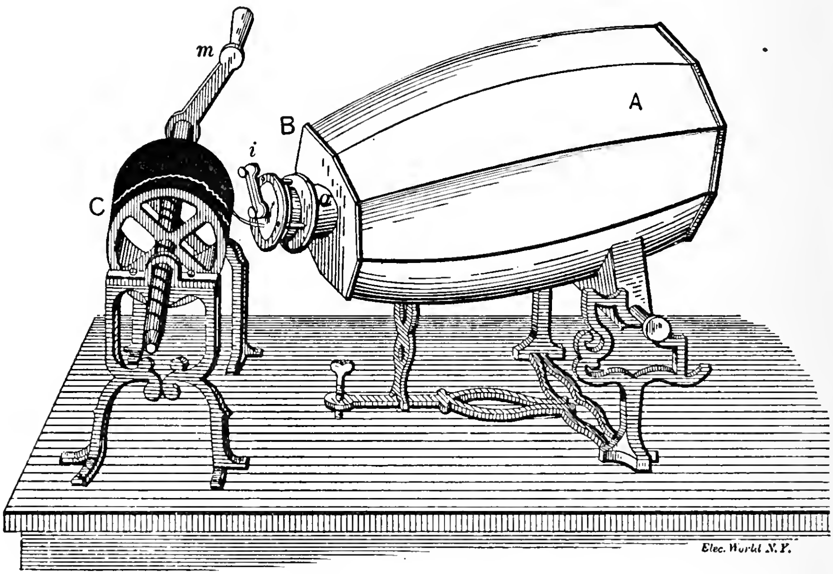
Bourseuil's ideas were immediately reprinted from French journals in other countries, and among the first was a prominent German semi-weekly journal, printed in Frankfurt-on-the-Main, *The Didaskalia*, which, on September 28, 1854, under the heading "Electrical Telephony," published a leading article, giving a full account of Bourseuil's ingenious and wonderful conception.

Frankfurt was then a city of about 60,000 inhabitants, and among other institutes of learning, it supported a Physical Society, which counted, at the time of this publication, among its active and most zealous members, an enthusiastic young teacher named Philip Reis, who, five years afterward, actually made an apparatus such as indicated by Bourseuil (who had since died without executing his idea). and which apparatus has since become known as the Reis telephone.

I will not now enter upon any controversy as to the scope of

this invention, regarding the possibility at the present day to transmit speech with the same. It may suffice to state that, when the news of the Bell telephone reached the learned men of Germany, some of the very first scientists in Berlin who knew all about the Reis apparatus, doubted the possibility of the performance as represented by the American press. It is also now a matter of history, that in the late decision in favor of Mr. Bell, the United States Supreme Court was unanimous so far as the Bourseuil-Reis apparatus was concerned.

FIG. 1.



Scott's Phonautograph.

While Bourseuil's conception was being digested by Reis, another invention, having also a membrane diaphragm as its motive principle, was patented in France in 1857. This was the phonautograph, by Léon Scott, which had for its purpose the recording of sound vibrations upon a cylinder rotated by hand and moved forward by a screw (Fig. 1). The cylinder was covered with paper, this was smoked over a flame, and a stylus attached to the centre of a diaphragm under the influence of words spoken into a large barrel-like mouthpiece, would trace sound vibrations

upon the smoky surface. Scott also employed an animal membrane for his diaphragm, and took pains, by means of an attachment called a sub-divider, to make the vibrations appear as large as possible. This sub-divider, however, became the prototype of the dampers in subsequent apparatus, like the Blake transmitter and the Edison phonograph.

The next important event in electro-phonic and acoustic science was the publication by Helmholtz of his investigations in sound, and of König in the same line of research, but classical as these publications will forever remain, they for a time retarded the progress of apparatus for practical use, for the reason that they discouraged inventors by the mechanical complications which they apparently ascribed as indispensable to articulate speech. In fact, the perusal of their work left a serious doubt in the mind of many a student, whether there was not something in articulate speech and its audibility by the human ear, beyond the grasp of the mechanical mind of man.

These doubts were still increased by the attempts of Faber to construct a talking machine, after the system of the human organs of speech, a mass of intricate mechanism, levers, bellows, and pulleys, which gave an unearthly rendition of many words and sentences.

But the Bell telephone came, and its greatness consisted not so much in the fact that it carried speech over hundreds of miles, but that it taught how simple a piece of apparatus could produce such perfect results, and that any diaphragm however thick, could be made to set up audible articulate vibrations.

The effect of this lesson was immediate, for hardly had the new wonder become known when an astonishing chain of logic formed in the brain of a distant devotee to science.

On the 30th day of April, 1877, Mr. Charles Cros deposited with the Secretary of the Academy of Sciences in Paris a sealed envelope, containing what in translation reads as follows:

"PROCESS OF RECORDING AND OF REPRODUCING AUDIBLE PHENOMENA."

"In general, my process consists in obtaining the tracing of the to-and-fro movements of a vibrating membrane, and the utili-

zation of this tracing for reproducing the same to-and-fro movements, with their relative inherent durations and intensities in the same membrane, or in another adapted for furnishing the sounds and noises which result from this series of movements.

"We are, therefore, concerned with the transformation of an extremely delicate tracing, such as that obtained with a delicate stylus rubbing upon a surface blackened by a flame, to transform, I say, these tracings in relief or intaglio, in resisting material capable of guiding a moving body, which transmits these movements to the sonorous membrane.

"A light stylus is connected with the centre of a vibrating membrane; it terminates in a point (metallic wire, the barb of a feather, etc.), which bears upon a surface blackened by a flame. This surface is a part of a disk to which is given a double movement of rotation and rectilinear progression.

"If the membrane is at rest, the point will trace a simple spiral; if the membrane vibrates, the traced spiral will be undulating, and these undulations represent exactly all the to-and-fro movements of the membrane, with their times and intensities."

Up to this point the apparatus as described would represent a modified Scott phonautograph, in which the cylinder is substituted by a flat disk. Mr. Cros then continues:

"By means of the photographic process which, in fact, is well known, this traced, transparent, undulatory spiral is converted into a line of similar dimensions, in intaglio or in relief, in resisting material like tempered steel, for instance.

"This done, this resisting surface is, by means of a motor apparatus, made to turn and to progress rectilinearly with a velocity like that which was used in the registration.

"If the reproduced tracing is in intaglio, a metallic point (and if it is in relief, a notched finger), held by a spring, bears upon the tracing at one end and is connected at the other end with the centre of the membrane adapted for sound reproduction. Under these conditions, this membrane is not any more acted upon by the vibrating air, but by the tracing controlling the pointed stylus by pulsations exactly like those to which the membrane was subjected in recording, both as to duration and intensity.

"The spiral trace represents the successive equal periods by its increasing and decreasing length. There is nothing inconve-

nient in this if only the outer portion of the rotating circle is used, and if the spirals are close together, except that the central part of the disk is lost.

"In all cases, however, a helical tracing upon a cylinder is much to be preferred, and I am actually engaged in finding a practical embodiment of this."

This paper was only read in open session at the Academy on December 3, 1877, and in the meantime Mr. T. A. Edison appeared with the phonograph.

From what we can learn by published reports, Mr. Edison, some time in the latter part of September in the same year, was at work on an automatic telephone, by which he intended to impress a telephone message upon a strip of tin-foil, and let the indentations thereby produced act upon a variable resistance, such as a lampblack button, and thereby transmit the message over the wire. While one day at work on this, so the report runs, he, perchance, slipped the previously indented slip under the recording stylus which, as in the Scott phonautograph, was connected to the centre of a diaphragm, and then and there occurred the first actual reproduction by mechanical means of words registered before.

The phonograph became then, at once, an accomplished fact, for to such an experienced inventor it must have taken but a moment to mentally cover the cylinder of a Scott phonautograph with tin-foil and to indent the same at right angles to the surface of the cylinder.

Everybody remembers the sensation which the invention produced, and the prognostications which were advanced for it by the scientific press showed that the principle of the apparatus was considered to contain the germ of an ultimate achievement of the most accurate results.

In this respect, as well as in others, there are striking resemblances in the history of the two inventions with which I am dealing.

In both, the original idea emanated from Frenchmen, and both described one process of transmitting, and a different process of reproducing speech. In the Bourseuil telephone there was a contact transmitter and an electro-magnet receiver; in the Cros

phonograph, a written record and an engraved reproducing groove.

In both inventions the first realization occurred in the United States, and was effected with apparatus representing only the reproducer of the original conception. In the speaking telephone, the reproducing electro-magnet of Bourseuil became also the transmitter of Bell, and in the phonograph, the reproducing groove and stylus of Cros became also the record of Edison. Both the Bell and Edison apparatus were accepted for a time as containing the best mechanical and philosophical principle for the highest attainable results. In both, the aim at the beginning was to produce loud sounds, and both eventually contented themselves with a much fainter voice, which then became more distinct in articulation. Finally, in both inventions, the original transmitter was subsequently resurrected, and found to contain a pointer toward a superior principle as a transmitter and recorder, and it only remains now to use a Scott phonautographic record direct for reproduction in order to complete a parallel with the fact that a contact transmitter can also be used as a telephonic reproducer.

In making these parallels, however, I am aware of the fact that Cros had a better idea of a talking machine than Bourseuil had of a speaking telephone.

The paper of Mr. Cros, which can be found on page 1082, vol. 85, of the *Comptes Rendus* of 1877, appears to have been consigned immediately to obscurity. When ten years later, I filed my patent application for the gramophone, not even the Examiners at the Patent Office knew anything of Mr. Cros, and when I mentioned his name in the first publication of the "gramophone," even those best informed on the subject were surprised. Nevertheless, I considered it a duty to my friends to make the following statement to the Editors of *The Electrical World*, which they published simultaneously with the "gramophone," on November 12, 1887. I said:

"On August 30, of this year, which was three months after the filing of my application for a patent, while in the office of my counsel, Mr. Joseph Lyons, I happened to look through a German scientific book in his possession, and reading up about the phonograph, I came across a remark stating that on April 30,

1877, one, Chas. Cros, deposited at the French Academy of Science a sealed paper which, when opened and read at a subsequent session during that year, was found to contain a description of the author's idea that a photo-engraved phonautographic record, either in relief or intaglio, might be utilized 'for reacting through a stylus on a diaphragm, and by this reaction ought to reproduce the original sound.'

"Surprised as I was at this discovery, I requested Mr. Lyons to find out through his friends in Paris whether and to what extent Mr. Cros had ever carried his idea into practice, and an answer has since come to the effect that Mr. Cros never put his idea into practical operation.

"Whether he was taken aback by the *éclat* which the phonograph produced soon afterward; whether he became discouraged at the practical difficulties, of which I have found many at the outset of all my experiments; or whether he did not appreciate the peculiar advantage of the phonautogramic method—all this does not appear from the meagre accounts so far to hand.

"But although, viewed in the light of equity, he had virtually abandoned his invention at the time when I independently and without knowledge of his prior idea took up the same subject, the fact remains that to *Mr. Charles Cros belongs the honor of having first suggested the idea of, and feasible plan for, mechanically reproducing speech once uttered.*"

As this statement has never been challenged since it was first made, I presume that it is substantially correct.

If we should attempt to carry out strictly the ideas of Mr. Cros, we would find many obstacles to obtaining practical results, and while undoubtedly the correctness of the general principle could be proved, the effects would not be as good even as those obtained by the original phonograph. Even with the application of the various improvements which I originally introduced, the process requires great care, and while this would not have been an obstacle on account of the great advances made in photo-engraving, I have now abandoned the original process altogether, and have substituted one of great rapidity and simplicity.

But to return to the phonograph, we find this apparatus remained in an unsatisfactory and unfinished condition for nearly nine years.

Among those who believed that ultimately the phonograph could be turned to practical account, was the well-known original patron of the speaking telephone, Mr. Gardiner G. Hubbard, and being also financially interested in it, he, in 1883 or thereabouts, caused the Volta Laboratory Co., an association originally founded by Prof. Bell as a laboratory, from the funds of the Volta Prize awarded to him by the French government, to provide ample funds for the purpose of making an extensive series of experiments with the phonograph.

Prominent among the scientists connected with the enterprise were Prof. Bell, Dr. Chichester A. Bell, and Mr. C. S. Tainter. After two years of ardent labors these gentlemen came to the conclusions:

First. That the indenting process had to be abandoned and an engraving process be substituted—*i. e.*, instead of pushing the record surface down with the stylus, as in the original phonograph, it should rather be dug out or graven into.

Second. That the best substance, answering also the various other requirements, was beeswax hardened by an admixture of paraffine, or other similar waxy substances.

Third. That loud speaking was impracticable, and that the ordinary conversational tone gave better results, although reducing the reproduction to the loudness merely of a good telephone message.

In Patent No. 341,214, of May 4, 1886, issued to Dr. Chichester A. Bell and Mr. C. S. Tainter, the following claims, among others, were granted:

"The method of forming a record of sounds by impressing sonorous vibrations upon a style, and thereby *cutting* in a solid body the record corresponding in form to the sound waves, in contradistinction to the formation of sound records by indenting a foil with a vibratory style, etc.

"3. The vibratory *cutting* style of a sound recorder; substantially as described.

"7. A sound record consisting of a tablet, or other solid body, having its surface *cut or engraved* with narrow lines of irregular and varied form, corresponding to sound waves substantially as described.

"9. The method of forming a sound or speech record, which

consists in engraving or cutting the same in wax, or a wax-like composition; substantially as described."

As a final result of all their labors, there issued in the spring of 1887, the graphophone, the first really practical apparatus of the phonograph type, and which was exhibited to admiring crowds in Washington and elsewhere.

To those who have never heard this instrument, I will repeat what I wrote about its performance in November, 1887, namely, that it appears to be the best instrument to take down business letters or dictations of any kind, in which the recognition matters little, so long as the words can be made out; also, that the reproduced sound is as loud as that of a good telephone message, but that the distortion produced by the engraving is sufficient to make the voice unrecognizable save to a strained imagination added to a previous knowledge of the author of the voice. The record ground of this machine is a thin pasteboard cylinder covered with wax.

Soon after the graphophone became generally known, Mr. Edison, evidently encouraged by the results obtained in this instrument, took again to experimenting with the phonograph, and, after trying wax covered with tin-foil for indentation, he abandoned that mode of recording, and also settled upon a cylinder of wax and the graving-out process, thus confirming the correctness of Bell and Tainter's conclusions, and the new Edison phonograph and the graphophone appear to be practically the same apparatus, differing only in form and motive power.

I now come to the subject of the evening, the Gramophone.

In my telephonic studies, I had become familiar with all the causes influencing the transmission and reproduction of the voice, and what had at all times struck me as forcibly as anything in telephonic phenomena, was the fact that the self-induction of long iron wires or of polarized electro-magnets acted so detrimentally upon the articulation. Electrical resistance alone would simply have weakened the sound, but self-induction meant retardation, and this distortion of the transmitted waves which varied in length and amplitude. To appreciate fully what an extremely small amount of energy ordinary speech possesses mechanically, let us consider a few well-known facts:

A puff of air, not strong enough to extinguish a candle-flame,

when blown across an empty bottle or into a whistle will produce a sound which may be heard over a hundred feet away. The amount of electricity needed to operate audibly a magneto-telephone, is said to be less than one-millionth part of the electricity of a standard Daniel cell.

In considering such and other facts it became evident to me that if such delicate energy, subdivided into maybe several hundred waves, should indent or engrave itself into a solid body, it needed but very slight mechanical resistance to modify considerably the character of the sound vibrations. For what self-induction is to the telephone circuit, the variable resistance which impressible material offers to indentation or engraving at various depths is to the phonograph record sheet. Neither is proportional in direct ratio to the expended energy and must give cause, aside from a reduction in size of the sound characters, also to a distortion of the same.

Your own Prof. Houston, in his learned remarks in the JOURNAL OF THE FRANKLIN INSTITUTE of January, 1888, says:

"The difficulties just pointed out, it would seem, must exist in any instrument, however improved in its mechanical structure, if it make the record on the Phonogram at right angles to the surface thereof. Of course, if a substance was discovered for such a surface, that offered a resistance to indentation exactly proportional to the depth of such indentation, the difficulty would, to a great extent, be removed."

All the experiments which were made with the phonograph and the graphophone, confirmed the correctness of all these assertions, for the louder it was necessary to speak when recording, the less distinct became the articulation of the reproduced sound.

A change for the better was, therefore, to be obtained:

First. By tracing the vibrations, as in the old phonautograph, parallel to the record sheet.

Second. By reducing the resistance offered by the record medium to as near to nothing as possible.

Both principles, although not emphasized, are contained in the Cros document; but for my part, I found that merely smoked surfaces were utterly impracticable, because, if sufficiently black for a photo-engraving, and with the extremely small sizes of

waves obtained with records that are adaptable for the reproduction of good articulate speech, the record lines were ragged, and, under a magnifying glass, looked like a set of parallel saws whose teeth would form a grating sound, which nearly drowned the articulation.

I observed, however, in my experiments, that the grayish deposit of lamp-black which is obtained from the centre of a kerosene flame was more oily and gave a somewhat sharper line than the deep black deposit caused by smoking with the top of the flame, and this led me to the highly beneficial process of oiling the plate prior to smoking the same, either by applying printers' ink or artists' paint by means of a printers' roller or by brushing oil over it. The smoke would then amalgamate with the oil and forms a *fatty ink* of a rather dry consistency, which, when crossed by a stylus, shows, even under a microscope, a sharply cut transparent line.

I still employ this process for small test plates and prepare them as follows: One part of paraffine oil is mixed with twenty parts of benzine or gasoline. This mixture is poured on and off a glass disk, when the benzine evaporates leaving an extremely thin layer of oil. This is held over a smoky flame and moved to and fro until the surface looks *just* dry. The application of artists' paint with a roller prior to smoking is still better.

I also adopted for the gramophone a disk of glass as a support for the smoke deposit, traced the sound record from below so that the displaced lamp-black should fall down, varnished it after the tracing was done and used this disk as a negative without, therefore, needing a camera or photographic chemicals outside of the chrome-gelatine or chrome-albumen used in developing a raised picture. I would refer, for a detailed account, to the already mentioned issues of *The Electrical World* and the JOURNAL OF THE FRANKLIN INSTITUTE.

The lesson of simplicity which the telephone was continuously preaching caused me at an early day to look for a simpler plan to attain my purpose, and in the specification originally filed by me I said:

"This record (meaning the phonautogram) may then be engraved either mechanically, *chemically*, or photo-chemically." And although for a long time without much hope for success, the

purely chemical process of direct etching haunted me continuously, and was repeatedly suggested by others.

But it was easier suggested than carried out, because under the principles of the gramophone the etching ground was to offer practically no resistance to the stylus, and to make one which had no resistance mechanically, but did resist the etching fluid after the tracing was done, was the problem to be solved.

You will readily see, that if we can cover, for instance, a polished metal plate with a delicate etching ground, trace in this a phonautogram and then immerse the plate in an etching fluid, the lines will be eaten in and the result will be a groove of even depth such as is required for reproduction; such a process, of course, would be much more direct and quicker than the photo-engraving method.

In nature provision seems to be made for all the wants of mankind, and confident in this belief, I kept on trying to find a trail which led to promising results, and I have the honor to-night, for the first time, to bring before you this latest achievement in the art of producing permanent sound records from which a reproduction can be obtained, if necessary, within fifteen or twenty minutes, and which can be accurately multiplied in any number, by the electrotype process. It may be termed, in short, *the art of etching the human voice.*

The etching ground which I use is also a fatty ink, and one of the best I have found thus far is made by digesting pure yellow beeswax in cold gasoline or benzine.

Benzine, in a cold state, will not dissolve all the elements of the wax, *but only a small part*, namely, that which combines with the yellow coloring principle, and the resultant and decanted extract is a clear solution of a golden hue, which gradually becomes bleached by exposure to light. The proportions which I use are one ounce of finely scraped wax to one pint of gasoline. The bottle containing the mixture must be repeatedly shaken, and, after the white residue has settled, the clear fluid is decanted or drawn off by a siphon.

I then take a polished metal plate, generally zinc, and flow the fluid on and off, as if I would coat with collodion. The benzine will quickly evaporate, and there remains a very thin layer of wax, iridescent under reflected light, not solid as a coating pro-

duced by immersion in a melted mass, but spongy or porous, and extremely sensitive to the lightest touch.

Partly on account of the too great sensitiveness of a single film, and also as an additional protection against the action of the acids employed in the subsequent etching, I may apply a second coating of the solution, and this double coat I find to answer all requirements.

The protection which this porous or spongy wax affords from the acid, is mostly due to the fact that watery solutions assume the spherical state on the film, while at the lines where the wax is disturbed the acid enters freely, and attacks the metal below.

A difficulty, which only a short time ago appeared insurmountable, was the accumulation at the point of the stylus, while tracing the sound record, of filamentary particles of dust which exist in the wax solution, and which being ever present in ordinary rooms, settle down and adhere to the film. These dust particles are so fine that they cannot, as a rule, be detected by the most searching inspection of the prepared plate; but they become very conspicuous, and a very serious source of annoyance when a long record is being made.

It must be borne in mind that the contact which the tracing stylus makes with the record surface, is obtained by the elastic pressure from a piece of hair-spring backed by a narrow blade of writing paper, and which pressure amounts to about five grains. Therefore, as this stylus passes through the fatty ink or other ground, and traces the fine undulatory line, the dust particles, as well as small portions of the displaced ink or wax adhere to and accumulate at the point of the stylus and are dragged along, and the record thereby becomes blurred and indistinct.

I have discovered an effective means for overcoming this difficulty, and it consists in applying to the record surface a fluid that slightly adheres to the etching ground, and keeps it wet while the record is being made. I have found commercial alcohol to be very effective for this purpose, and it is used by pouring it over the plate just before the sound record is made. The alcohol, of course, immediately commences to evaporate, but not rapidly enough to disappear entirely before the record is finished, and there is no difficulty in adding more alcohol while the plate revolves. Under this condition, the point of the stylus remains

perfectly clean, and it seems as if the dust particles had not been present at all.

The theory by which I explain this result is, that the alcohol, so to speak, lubricates both the surface and the stylus, and prevents the adhesion of the filaments to the latter. At any rate, the application is highly beneficial, and the resulting line is so sharp and fine that it has to be widened in the subsequent etching process, in order to permit the acid to bite at sufficient depth. It can also be proved that the resistance of the wax film is decreased by the presence of the alcohol, but when this has evaporated the wax film appears to be in precisely the same condition as before, even showing again the iridescent colors which disappeared on the application of the alcohol.

The film of wax being so thin, it is almost transparent, and if th erecord was made on this it could barely be detected. As, however, it is sometimes desirable to examine the record prior to etching the same, I can smoke the etching ground slightly by holding it high above burning camphor, so as to prevent a heating and melting of the spongy wax, and the alcohol poured afterwards over this smoked surface does not seem to wash off any of the soot particles.

We now come to the important process of etching the record. Etching is done on steel, copper, or brass with nitric acid, perchloride of iron, or with a mixture of muriatic acid and chlorate of potash known as Dutch mordant. In modern photo-engraving nearly all the etching is done on zinc by means of diluted nitric acid, and these materials are preferred on account of their being cheaper than any other, and zinc is a metal easily obtained with smooth and even facings. In etching, however, on zinc, it is necessary continually to brush away the hydrogen bubbles which form and adhere to the lines, and as the etching ground is usually of firm and solid material (like asphaltum, hard wax, pitch, or rosin mixtures) no harm results from the brushing necessary in order to obtain sharp edges along the lines.

Desiring to avail myself of the advantages offered in zinc plates, I soon found that no etching fluid was known that would be to zinc what perchloride of iron was to copper—namely, etch cleanly and without the appearance of hydrogen bubbles. To apply the brushing to the delicate spongy wax film

I employed was out of the question, as the first touch would wipe away the whole ground, and to permit the formation of hydrogen bubbles without brushing them away meant uneven and ragged lines and a distorted record.

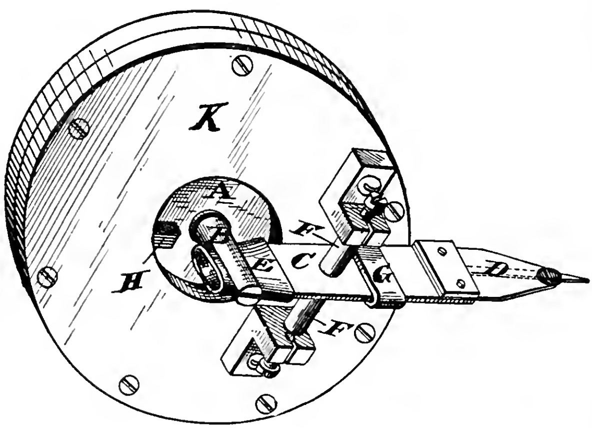
While studying this matter over it occurred to me to, so to speak, depolarize the zinc plate by adding to the acid, bichromate of soda which I thought might prove efficient, as it does in the galvanic battery, to prevent the appearance of the bubbles while etching the zinc. It took, however, a comparatively large quantity of the bichromate to answer my purpose, so much that I concluded that the mixture had all the conditions of a chromic acid, or at least of a mixture of chromic acid and nitrate of soda. When I thereupon substituted a solution of chromic acid pure and simple, I found this to be a most excellent etching fluid, and that is what I am now using—namely, a solution of one part by weight of dry chromic acid dissolved in three parts by weight of water. I use the commercial acid, such as can be obtained from Churchman & Co., of this city, at twenty-five cents a pound. Such a solution etches on zinc a sharp and clearly cut line, and no hydrogen appears during the etching.

The back of the zinc plate had previously been painted with protecting varnish or molten beeswax, and within from fifteen to twenty minutes from the time of immersion in the chromic acid solution, and without disturbing it a cleanly cut groove of sufficient depth is obtained for reproduction. This groove may then be deepened in the ordinary way of rebiting by covering the facing of the plate with rosin dust, heat the same, and then immerse in diluted nitric acid. Under these conditions the brush may be applied until the necessary depth is obtained, generally in about one to three minutes according to the strength of the etching fluid. I have used stronger solutions of chromic acid with no ill effects and a more rapid etching, and there seems to be a wide margin on this point, provided the plate is watched during the etching process. The lines very gradually widen in the course of the etching, but the upper edges of the grooves remain perfectly parallel and sharply defined.

Before proceeding with a practical demonstration of the whole process, I will now describe the most important apparatus of the gramophone, the recorder. The translation of the movements of

the diaphragm into the same movements at right angles, and with the extreme smallness of the motion and the liability of distorting them, adding to them, or detracting from their value in translating them, requires greater care to guard against error than an uninitiated observer would suppose, and when we examine the complex and extremely delicate mechanism which nature has provided in the human ear for giving a correct translation of air vibrations into nervous vibrations, it behooves us to be careful in the application of every day mechanics. Free as the telephone is, comparatively, from mechanical incumbrances, it is deficient in articulation of the consonants, and with the simplicity of mounting as required in the phonograph and graphophone, these difficulties of recording proper do not exist, and are shifted to the other portions of their construction and manipulation. In having attempted, therefore, to do justice to all sources of error I am not yet prepared to say that my present recording apparatus is constructed and adjusted to the greatest attainable correctness. Those who are familiar with the tediousness of original research will admit that a new subject of this kind cannot be solved in its entirety within the space of a few months, and what I bring before you to-night being the hasty results of a new machine finished but ten days

FIG. 2.



ago, should be measured rather by the possibilities it opens, than by the results so far attained, whatever merit you may accord to them.

My impression, however, is that there is very little of lost or added motion in my present apparatus, and whatever imperfections may exist must be looked for in the mode of reproducing the sound, rather than in the recorder (Fig. 2).

K is the diaphragm box; *A* is the centre portion of the diaphragm; *B* is a brass post screwed to the diaphragm and slotted above; *E* is a piece of rubber tubing held in the slot and holding one end of the stylus *C*. This stylus is made of stiff metal and is pivotted by the steel pivots *F F*. *D* is a blade of writing paper reinforced by a piece of hairspring which extends, and forms the tracing point. *G* is a piece of rubber tubing around the stylus which dampens its musical vibrations; *H* is a piece of felt damper between the diaphragm and the diaphragm box, which acts as a general damping device.

The whole is mounted on a sliding carriage, which is drawn by clock-work across the disk, while the latter revolves at the rate of about thirty revolutions per minute.

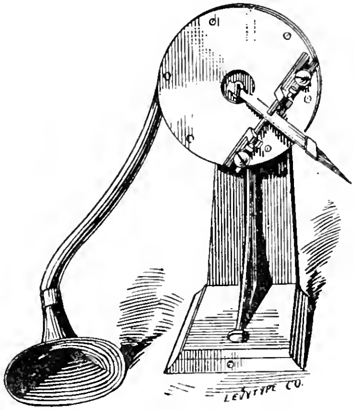
DEMONSTRATION.

While the plate is being etched I will now let you listen to some phonautograms which I prepared in Washington within the last two weeks. The reproducing apparatus, or sounder, is constructed on precisely the same principles as the recorder, but of smaller dimensions and with more rigid mountings, so rigid, in fact, that if it was used as a recorder it would barely show undulations on a smoked surface when shouting into it.

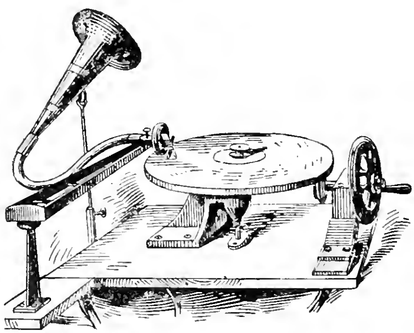
The stylus is tipped with iridium like the points of a gold pen, the object of this being to prevent abrasion by the continuous friction with the hard record.

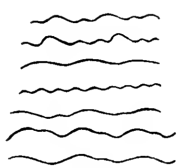
In reproducing the sound, I find that it is louder with hard contact substances, like metal, than with soft ones like rubber or plaster-of-Paris. Hard metals like copper, nickel, or brass, sound louder than zinc or type-metal, but the scraping sound, which is due to friction, is also increased unless the record surface is smooth and very highly polished.

But when an iridium-pointed stylus is rubbed over clean glass a scraping sound is barely perceptible. I am now in communication with a firm that is making ornamental glass tiles by im-



Recording Diaphragm and Stylus.


Reproducing Apparatus.


Record lines (magnified 6 diameters).

pressing upon red-hot glass plates fancy designs in relief or intaglio by strong pressure. You will readily see that if on the same plan we can impress a matrix showing the sound record in raised lines upon a glass plate, we would get a groove, in glass giving a loud reproduction with a minimum of disturbing sound due to friction.

In the description of November 12, 1887, I advanced the idea of mounting the sounder on a carriage and rails, and have the record groove itself be the screw which was to guide the point of the stylus across the disk from periphery to centre. This has been improved upon by Mr. Werner Suess, the gentleman with me here to-night, and who is the mechanician of our little shop in Washington. He suggested to mount the sounder on a pivot at some distance from the disk and then let the reproducing groove guide the sounder across the disk over an arc of flat amplitude. This happy idea is embodied in the present apparatus, and is a very ingenious adaptation indeed.

REPRODUCTION.

It is, I trust, pardonable if I close by foreshadowing to a certain extent the practical applications of the gramophone.

A standard reproducing apparatus, simple in construction, and easily manipulated, will, at a moderate selling price, be placed on the market.

Those having one, may then buy an assortment of phonautograms, to be increased occasionally, comprising recitations, songs, and instrumental solos or orchestral pieces of every variety.

In each city there will be at least one office having a gramophone recorder with all the necessary outfits. There will be an acoustic cabinet, or acousticon, containing a very large funnel, or other sound concentrator, the narrow end of which ends in a tube leading to the recording diaphragm. At the wide opening of the funnel will be placed a piano, and back of it a semicircular wall for reflecting the sound into the funnel. Persons desirous of having their voice "taken" will step before the funnel, and, upon a given signal, sing or speak, or they may perform upon an instrument. While they are waiting the plate will be developed, and, when it is satisfactory, it is turned over to the electro-

typer, or to the glass moulder in charge, who will make as many copies as desired.

The electrotype shells are mounted on thick pasteboard, and this is backed by a stiff piece of sheet metal. There is another process which may be employed. Supposing that his Holiness, the Pope, should desire to send broadcast a pontifical blessing to his millions of believers, he may speak into the recorder, and the plate then, after the words are etched, is turned over to a plate-printer, who may, within a few hours, print thousands of phonautograms on translucent tracing paper. These printed phonautograms are then sent to the principal cities in the world, and upon arrival they are photo-engraved by simply using them as photograph positives. The resultant engraved plate is then copied, *ad infinitum*, by electrotyping, or glass moulding, and sold to those having standard reproducers.

Prominent singers, speakers, or performers, may derive an income from royalties on the sale of their phonautograms, and valuable plates may be printed and registered to protect against unauthorized publication.

Collections of phonautograms may become very valuable, and whole evenings will be spent at home going through a long list of interesting performances. Who will deny the beneficial influence which civilization will experience when the voices of dear relatives and friends long ago departed, the utterances of the great men and women who lived centuries before, the radiant songs of Patti, Campanini, Nieman, and others, the dramatic voices of Booth, Irving, and Bernhardt, and the humor of Whitcomb Riley can be heard and re-heard in every well-furnished parlor?

Future generations will be able to condense within the space of twenty minutes a tone picture of a single lifetime. Five minutes of the child's prattle, five of the boy's exultations, five of the man's reflections, and five of the feeble utterances from the death-bed. Will it not be like holding communion even with immortality?

POSTSCRIPT: One of the peculiarities inherent with the gramophone is the possibility to enlarge the original sound by enlarging the printed vibratory characters of speech and then photo-engrave

the same. In this manner it should be possible to get the reproduction at a much greater volume than the original sound. It would be interesting if some day speakers in a large hall would prefer to do their talking by machine, or to send speeches to a convention which they were unable to attend in person.

E. B.

[At the close of the paper and after the exhibition of the apparatus, Prof. E. J. HOUSTON moved a vote of thanks to MR. BERLINER for his interesting and valuable communication. The motion was carried unanimously, and the meeting was adjourned.]

THE PILOT CHART OF THE NORTH ATLANTIC OCEAN,

ISSUED MONTHLY BY THE UNITED STATES HYDROGRAPHIC OFFICE.

BY EVERETT HAYDEN, in charge of the Division of Marine Meteorology, United States Hydrographic Office.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January 27, 1888.*]

Concluded from Vol. CXXV., page 278.

Perhaps the most characteristic as well as the most important data published on the chart are the "red data," comprising as they do all matters of special immediate importance and interest. The final proof of this impression is corrected and revised at the last moment before going to press, for this portion of the chart aims to give the latest and most trustworthy *news* regarding various subjects of great importance to navigators. The long list of Notices to Mariners gives, in brief, the title of each notice published during the month just passed, indexed in such a way that each one can be readily referred to and called for by number. These notices can be obtained, free of charge, at any branch hydrographic office, and the master of a vessel about to sail for a distant port can consult this list and obtain the latest information regarding the navigation of the waters which he has to traverse.

The preparation of these notices, of which only the titles are given in this list, is carried on by the Division of Sailing Directions, and is a work of great magnitude, involving the most painstaking care, accuracy and thoroughness. Hydrographic information received from various foreign offices, correspondents and publications, must be quickly and carefully collated, verified and prepared for publication according to the prescribed form and the proof very carefully corrected, for this is a case where a slight error in a single figure may make an item worse than useless. The same may be said regarding the next column, a list of dangerous obstructions to navigation along the coast. The stranded wrecks, whose positions and descriptions are stated as accurately and yet as concisely as possible in this list, constitute each one a dangerous obstruction, all the more dangerous because not shown on any chart, nor, in most cases, marked by any buoy to warn the navigator. Except among those whose profession compels them to recognize the fact, it is not generally known that a sunken and dismasted wreck near the coast may be a source of danger for months, and even years, to other vessels. For this reason, every effort is made to keep this list corrected up to date by means of all available information, and whenever a suitable opportunity occurs, a naval vessel is detailed for the purpose of blowing up or otherwise removing one or more of these obstructions, guided by information furnished by the Hydrographic Office. Then follows a list of charts published during the preceding month, and a list of those that have been cancelled for one reason or another, and are no longer issued. Here again we are given an insight into the workings of another and perhaps the most important of all the Divisions of the Hydrographic Office, the Division of Chart Construction. Had I an entire evening to devote to this one subject, I could hardly begin to give even an outline of all the scientific principles, and the exact and refined mechanical processes, involved in the preparation of one of the large copper plates from which these hydrographic charts are printed. Although the mere estimated cost in dollars and cents of the material, drafting and engraving is but a poor index to the amount of skill, labor and expense which each of these copper plates represents, it must suffice to say here that the estimated cost of a single plate (H. O. Chart No. 981, S. E. coast of Nova Scotia, etc.), including cost of changes and

corrections charged up against it, is $1,672.10, and that there are now on hand, carefully stored away in readiness for use as occasion demands, 429 plates, each of which must be carefully corrected up to date by constant reference to all the latest information received, in order that the office may always be in readiness to print new editions of any chart that may be called for. Thus the Pilot Chart, although published under the supervision of the Division of Marine Meteorology, records and publishes an abstract of the work which is being carried on in each division of the Office, in order that the results may be known and thus made available for immediate practical use.

The remaining space on the chart, available for printed matter, is devoted to such matters of special interest as come up from time to time, and to the publication of anything which it is desired to force upon the notice of navigators in such a way that it cannot be overlooked or forgotten. Perhaps the most notable success that has been achieved in this way has attended the publication of notices recommending the use of oil to prevent dangerous seas from breaking on board vessels—a source of very great danger during heavy weather. Without any exaggeration, it may be safely said that the revival of the knowledge of this old but forgotten principle, brought about within the last few years by means of such notices published on the Pilot Chart, has been of incalculable benefit to the commerce of the world. Let me quote a few such reports which have been published on the Pilot Chart during the past year:

Captain Campbell, American steamship *Knickerbocker*, was caught in the hurricane of August 22d, latitude 33° 23′ N., longitude 75° 15′ W. At 9 P. M. of the 23d, shipped heavy sea on port side, smashing in bulwarks; later, shipped sea on starboard side, washing away port life boat, gangways, fire buckets and racks, after compass, two ventilators, and stove out bulwarks. At 1.30 A. M., August 24th, frightful cyclone from W.NW., velocity approximately 100 miles, immense cross sea, ship laboring heavily. At 5 P. M. steering gear carried away. Used whale oil in sacks over weather (starboard) quarter to lessen the effects of heavy seas, with complete success, vessel riding easier while repairing. Captain Campbell speaks with enthusiasm as to the efficacy of oil.

Captain Brown, American barkentine *Josephine*, reports: August 27, 1887, passage from Turk's Island to Philadelphia, in a frightful sea, when it was almost impossible to get forward or aft, and utterly impossible for the cook to keep fire in the galley, as the vessel was putting her bows right under and

throwing heavy bodies of water aft, flooding the forward house and cabin and carrying away the port fore rigging and backstays, put raw linseed oil into bags in the usual way (one on the cathead and another in the main rigging), and after this the decks were comparatively dry.

Captain Morgan, British steamship *Blackwater*, encountered a terrible gale November 1st, near Liverpool, during which his vessel shipped a great deal of water. The seas were frightful. At one time it is estimated that the steamer had 100 tons of water on deck. Deciding to return to Cardiff for shelter, he stationed a hand at each bow to pour oil upon the water, when the seas, which had been most turbulent, ceased to break over the vessel. On more than one occasion it seemed as if nothing could prevent her from foundering, but Captain Morgan attributes her safety chiefly, if not solely, to the judicious use of oil.

With such items before him day after day as the navigator plots the track of his vessel on the chart, it is not surprising that thousands of mariners have been induced to try the experiment for themselves, and, whatever theorists may say to the contrary, it needs but a single trial to convert the most skeptical. As a result, the importance of this simple and inexpensive precaution is now recognized by every commercial nation, and no master of a vessel can afford to neglect it when heavy broken seas threaten to come on board. It is interesting in this connection to read what eminent foreign authorities say on the subject. Vice-Admiral Cloué, of the French Navy, in a recently published pamphlet, uses these words: "Between 1830 and 1840, several Dutch savants studied the subject carefully, and, having become convinced of the efficacy of the use of oil, induced certain sea captains to try this method of quieting the sea. But with the exception of a few cases where it was used successfully between 1845 and 1870, of which details are wanting, nothing was done. The question appears to have been forgotten until the Hydrographic Office at Washington took it up within the last few years, when it was pushed so vigorously and persistently that it is extremely unlikely ever again to fall into oblivion. By so doing, the Hydrographic Office at Washington has rendered an immense service to all seafaring men, and has placed them under great obligation." In a brief review of this pamphlet, Capt. W. J. L. Wharton, R. N. Hydrographer to the British Admiralty, writes as follows: "That the great effect produced by oil in smoothing troubled waters should have been so well known in times past as to have passed into a proverb, and yet that no general practical use of this effect should have been made until the last few years, is

a remarkable instance of the tardiness of mankind to apply the benefits that natural phenomena provide. To the Hydrographic Office of the United States is mainly due the credit of bringing into prominence, and forcing on the notice of seamen, in various publications, the great importance of this property of oil under circumstances when life and property are endangered by breaking seas, and the extreme facility and trifling expense of its employment. Thanks to the efforts of the Americans, the facts are now well known to all English-speaking mariners, and many are the instances of the successful use of oil; but, nevertheless, the préjudices of many are still against it."

The only remaining printed matter accompanying the red data is the brief weather review of the preceding month, published in the lower right-hand corner of the chart. This is prepared from all reports received up to the time of going to press, and gives, in connection with the storm tracks plotted on the chart, as complete a review as can be given from the data at hand.

In this description of the red data I have left to the last what may perhaps be regarded as the specially characteristic and interesting feature of the Pilot Chart. Derelict vessels, wrecks and drifting buoys constitute formidable obstructions to navigation at sea; indeed, it is not generally realized how long a derelict may keep afloat and pursue its aimless course at the mercy of the winds and currents of the ocean. To illustrate, let me quote three instances, the first two from the Pacific ocean, and the third from the North Atlantic:

Ship *Ada Iredale*, voyage from Androssan, Scotland, to San Francisco, was burned in the South Pacific through the spontaneous combustion of the coal with which she was laden. Abandoned October 15, 1876 (latitude 13° 30′ S., longitude 107° 45′ W.), about 1,900 miles east from the Marquesas Islands. The crew of twenty-three men reached the Marquesas group in twenty-five days, with the loss of one man and one of their three boats. The still burning wreck of the vessel drifted slowly to the westward, in the south equatorial current, to Tahiti, Society Islands, 2,423 miles distant, and was towed into port by the French cruiser *Seignelay*, June 9, 1877. She continued to burn till May, 1878, when she was repaired, and, as a handsome bark named *Annie Johnston*, has done good service in the trade with China. Drift, 2,423 miles; time, nearly eight months.

Ship *Oriflamme*, abandoned on fire in June, 1881 (latitude 18° 12′ S., longitude 92° 42′ W.). On October 24th, the steamship *Iron Gate*, voyage from Adelaide, Australia, to Portland, Oregon, passed, in latitude 13° 27′ S.,

longitude 125° 19′ W., an iron ship apparently burned, no masts standing; sent a life-boat alongside, but could see no signs of life. February 12, 1882, the hull of an iron ship, laden with coal and iron, drifted ashore on the Island of Raroia, one of the Paumotu or Low archipelago (latitude 15° 55′ S., longitude 142° 12′ W.). She was visited by some natives, who brought away a small bell upon which was engraved *Oriflamme, 1865*. She was completely burned out, and in a short time sunk in deep water. Drift, 2,840 miles; time, about eight months.

Abandoned schooner *Twenty-one Friends*. First reported March 24, 1885, about 160 miles off the capes of Chesapeake Bay (latitude 36° 45′ N., longitude 72° 40′ W.). The Gulf Stream carried her in a direction about E. NE. to latitude 51° 30′ N., longitude 27° 40′ W. (2,130 miles in four and one-half months). Thence she drifted in an easterly and southeasterly direction towards the northern coast of Spain, and was last reported December 4th, of the same year, in latitude 45° 00′ N., longitude 8° 00′ W., about 130 miles N. NE. from Cape Finisterre. She was reported, in all, twenty-two times, which in itself shows how especially dangerous such a derelict is on the North Atlantic. Drift, 3,525 miles; time, eight months and ten days.

In the preparation of the Pilot Chart every effort is made to collect all possible information regarding such derelicts, drifting buoys, and wreckage of a character likely to constitute a dangerous obstruction; in each case the latest reported position is plotted on the chart, with a line of dashes to indicate the track followed since the first report was received. Thus not only are navigators warned of this source of danger, but important data are being constantly recorded relative to the drift of ocean currents. I may therefore digress a moment to refer briefly to the general features of oceanic circulation in the North Atlantic. The principal factor is, of course, the great warm current known as the Gulf Stream, whose character and limits are so well known as to render it unnecessary now to describe it in detail, and I need only say that it, like all great warm ocean currents, follows very closely the general course of the prevailing winds, to which its existence is very largely due. As has been already pointed out, a noticeably constant area of high barometric pressure exists over the North Atlantic about the Azores and the region to the southwestward of these islands, and the general atmospheric circulation about this area is in a direction with the hands of a watch. To the southward, the prevailing winds are therefore easterly (the well-known northeast trades), while to the northward westerly winds prevail, as is graphically illustrated on the Pilot Chart. Keeping

this great general law of atmospheric circulation clearly before the mind, the general law governing the oceanic circulation follows directly from it. In the region of the trades there is found the great equatorial drift current, a general surface motion carrying the warm waters of the tropics slowly and steadily to the westward into the Caribbean Sea and Gulf of Mexico, whence the greater portion flows in a comparatively narrow and rapidly moving stream to the northward through the Straits of Florida, spreading out and moving more and more slowly as it gets farther north, and finally merging into the broad easterly drift current which flows towards the shores of Europe; here it is again diverted by the influence of land barriers and prevailing winds, and flows partly to the northward along the coast of Ireland and partly to the southward past the coast of Africa. To replace the great volume of water which thus circulates from the tropics toward the polar regions, the cold polar waters flow slowly to the southward, as a rule at the bottom of the sea, but to the eastward of Newfoundland as the cold Labrador current, which brings down icebergs during the spring and summer months and carries them into the track of transatlantic steamships to the southward of Newfoundland; thence it creeps along the Atlantic coast of North America as far south as Hatteras.

Every navigator knows, however, that the surface currents which he has to deal with are subject to many variations from these general laws, due to the temporary influence of the tides and to the effect of strong winds from other directions than those of the prevailing winds; also, that they are greatly modified near the shore by the configuration of the coast. Recent investigations by Lieut. J. E. Pillsbury, U.S.N., commanding the Coast Survey steamer *Blake*, have also developed the important fact that the Gulf Stream is subject to a noticeable and regular influence due to the moon, and that there is a daily variation in velocity, the time of maximum velocity off the south coast of Florida invariably preceding the time of the moon's upper transit by from seven to ten hours; and, moreover, that there is a monthly variation, the maximum in this case being reached two or three days after the time of the moon's greatest declination. These important results have been obtained by anchoring the *Blake* in very deep water, and taking current observations continually by means of an indicator,

which is sent down the wire rope by which the vessel is anchored; thus the velocity can be recorded at any depth desired. These observations are to be continued this winter by the *Blake*, and she will anchor in the equatorial current off the coast of South America and the Windward Islands, in from 100 to as many as 2,500 fathoms of water, a depth of nearly three miles.

A study of back numbers of the Pilot Chart, on which are plotted the latest reported positions and the tracks of derelict vessels and drifting buoys, furnishes an instructive illustration of the general course followed by such obstructions to navigation, as well as the great variations to which these general laws are subject.* Derelict vessels and drifting buoys which first appear near our coast south of Long Island and north of Hatteras, usually drift in a southerly direction, following the inshore current, until they reach Hattaras, where they are driven into the Gulf Stream and there take the direction of the latter. If a derelict be upright, and a northwest or west wind blowing at the time, the vessel will be driven into the stream much sooner than if it were bottom up, or if the winds were variable. The bark *Akbar*, which was wrecked off Savannah, August 27th, drifted up along the coast until it reached Hatteras, while another vessel wrecked a few days later off the Chesapeake, drifted south along the coast till it reached about the same point as the *Akbar*, when both entered the Gulf Stream, there to take the usual northeasterly course. Vessels wrecked between the eastern edge of the Gulf Stream and the Bermudas seem to take no direction in common until they are driven westward and enter the Gulf Stream north of the thirtieth parallel; they circle about for months, influenced mainly by the winds. The most notable case of this kind is that of the schooner *Ida Francis*, wrecked March 16, 1886. This vessel, after crossing and re-crossing its own track a number of times, drifted on the north shore of the island of Abaco, January 6, 1887, nearly ten months later. Similarly, the schooner *Mary E. Douglass*, wrecked August 22, 1887, north of the Bahamas, after circling about for two months drifted ashore at Green Turtle Bay, Abaco, very close to where the *Francis* went ashore. Derelicts abandoned in the "forties" east of the fiftieth meridian are generally carried into northern latitudes

* Illustrated on the screen by means of a lantern slide, showing many notable tracks of derelict vessels.

by the upper branch of the Gulf Stream, or general northeasterly drift current which sweeps the west coast of the British Isles; or else by the other branch to the west coast of Europe, there to enter the Bay of Biscay and the Rennell current, or else to be carried to the southward along the west coast of the Spanish peninsula. A recent and good instance of the northeasterly drift in the Gulf Stream has been furnished by the life raft of the steamship *Manhattan*, which was washed overboard during a hurricane, August 20th, in lat. 30° 50′ N., long. 74° 45′ W. It was reported November 11th, lat. 41° 13′ N., long. 46° 16′ W., having drifted 1,512 miles in two months and twenty-two days, an average of about eighteen and one-half miles a day. The great log raft, when abandoned off Nantucket Shoals on the 18th of December, was directly in the track of transatlantic steamships, and it is good cause for congratulation that it broke up before causing some great disaster. To the student of ocean currents, it will be interesting to watch the tracks which the scattered logs from this great raft will follow, drifting, as they do, under the combined and varying influence of wind, tide and current, and every log offering some slight difference of resistance to each, according to its size, weight, and depth of flotation. To the practical navigator, however, it will be of still greater interest to have logs shipped in the usual way, or at least more securely than was done in this case, in order that dangerous obstructions may not be added in this wholesale manner to those which, in the ordinary course of things, he has to guard against.

By thus following on the chart the drift of derelicts and wreckage they can generally be traced to that part of the ocean lying southwest of the Azores and south of Bermuda; that is, somewhere within the great elliptical area known as the Sargasso Sea, where the currents are slight and variable. Here they circle about for a long time, and either break up or become waterlogged and sink.

Icebergs often get as far south as the fortieth parallel before they melt and disappear. Immersed, as they are, to a great depth, their drift is mainly due to a strong undercurrent. In the same region and at the same time a drifting buoy, which is generally the best indicator of a surface current, would in all probability take a southwesterly direction and follow the Labrador current down the coast; thus a buoy which was reported November 2d, in lat. 46° 20′ N.,

long. 48° 35′ W., was reported December 25th, in lat. 40° 35′ N., long. 69° 15′ W., 900 miles W.SW. from where first reported, an average drift of about seventeen miles a day. Icebergs, however, plow their way into the Gulf Stream to the southward, the difference of direction being partly due to the force of the prevailing winds, but still more to the fact that the cold Labrador current under-runs the Gulf Stream, and by acting on the deeply immersed bergs overcomes the effect of the surface current.

In order to illustrate which months are the ones during which ice is most likely to be encountered off the Grand banks, I have had twelve diagrams (one for each month) prepared in such a way as to be shown together on the screen. On these diagrams the ice reported during each month of the past year is plotted, by means of a conventional sign, in the exact position where each berg or field was reported. It will thus be seen at a glance that February is the month during which icebergs and field-ice begin to be a source of great danger to transatlantic navigation, and this danger continues until the end of August. These diagrams show that, although during January of last year only six reports of ice were received, and these only off St. Johns, Newfoundland, there were plotted on the chart for March more than 100 icebergs and masses of field-ice, reported during the month of February. For this reason the transatlantic routes recommended during the spring months are well to the southward, clear of the probable limit of drifting ice.

This ice consists of field- or floe-ice, which is formed on the surface of the sea during the polar winter, and of icebergs, gigantic masses which break from the glaciers along the coasts of Greenland. With the exception of some field-ice which gets into the Gulf of Newfoundland through the Straits of Belle Isle, this ice is all carried to the southward, past the eastern coast of Newfoundland, and is liable to be encountered off the Grand banks as far south as 40° N. latitude, between the forty-second and fifty-second meridians; indeed, bergs have been reported as far south as the thirty-sixth parallel. A glance at the record of losses and casualities caused by ice last year on the North Atlantic calls attention very forcibly to this class of dangers: several vessels sunk by collision; others caught in heavy field-ice, driven ashore,

or otherwise damaged and delayed; many steamships reaching port with plates stove, rudders carried away, or blades of propeller gone. It is recommended to make free use of the thermometer, although experience shows that too much reliance should not be placed upon it. Experiments made in recent years show that warning may often be obtained by means of the echo thrown back from the surface of an iceberg when a vessel's whistle is sounded, or any sharp noise is made, and apparatus has been invented to utilize the echo to determine the direction and distance of the ice. No possible precaution should be neglected, especially during snow or fog, but the safest course of all is to take a southerly route, well clear of the probable ice limit.

Icebergs have been reported off the Grand banks with a height of more than 200 feet above the surface of the sea, and, from the known depth of flotation of solid ice, such a berg must ground on the Grand banks, there to remain as a new and uncharted island until it dissolves sufficiently to be drifted farther to the southward into the Gulf Stream, where it rapidly melts and disappears. A berg just clearing the bottom of the sea at the 100-fathom curve would have only 100 or 120 feet above the surface; indeed, a solid block of ice is even more deeply immersed. There can be no doubt that the formation of the Grand banks is largely due to masses of sand and soil brought down by icebergs during past ages and deposited where the bergs are melted by the warm waters of the Gulf Stream. Were it not for this great warm current, ice would be a source of danger much farther to the southward. The ice in the North Atlantic during the northern summer cannot be compared either in quantity or size with that brought down from the Antarctic zone into the South Atlantic, between the Falkland Islands and the Cape of Good Hope, during the summer months of the southern hemisphere. Thus one mass of ice which was reported by twenty-one ships from December, 1854, to April, 1855, from 44° S. 28° W., to 40° S. 20° W., was about sixty miles long and forty miles broad, with an elevation above the surface of the sea of fully 300 feet.

I have already referred in the earlier part of my lecture to the fact that supplements to the chart are occasionally issued. With the September chart, for instance, there was issued a supplement

descriptive of West Indian hurricanes, with practical directions for avoiding the dangerous regions of the storm disc, and with the December chart, a supplement descriptive of the winter storm belt of the North Atlantic, with a discussion regarding the best routes for transatlantic navigation.* Such supplements are not issued regularly, but only when some subject of special interest comes up which cannot be discussed or illustrated fully on the Pilot Chart itself. In addition to such occasional supplements, there is issued regularly on Friday of each week what is called the *Weekly Supplement*, a printed bulletin containing brief mention of all late reports of dangers to navigation, changes in lights and buoys, etc., along the Atlantic and Gulf coasts. This publication is intended primarily for the benefit of coasting vessels, and is found very useful, giving, as it does, a digest of all important news received during the week preceding the date of publication. The area covered by this weekly bulletin comprises, roughly speaking, the Gulf of Mexico, Straits of Florida, and that part of the Atlantic north of a great circle from Nassau to the English Channel, and south of a great circle from St. Johns, N. F., to the south of Ireland. From all this area many reports are received less than seven days old. A similar bulletin is published by the branch hydrographic office in San Francisco for the benefit of the coasting trade of the Pacific slope.

I can only refer very briefly to the methods by which reports are collected from masters of vessels, and to do so must first of all refer to the branch hydrographic offices established in six of our principal sea ports—Boston, New York, Philadelphia, Baltimore, New Orleans and San Francisco. It is almost self-evident that upon the efficiency of these branch offices depends, not only the success of the Pilot Chart, but to a large extent the effective working of the entire office. This fact is well attested by the strong support which they have received from the maritime community, and the popularity which they have won among masters of vessels, who can there find all the latest nautical information—charts, light lists, sailing directions—for every ocean of the globe, and standard barometers and thermometers for purposes of comparison.

* A copy of the supplement to the March chart, descriptive of waterspouts off the Atlantic Coast of the United States during January and February, 1888, is issued herewith.

The naval officer in charge of such a branch office, during his three years' tour of shore duty, is thrown into intimate relations with the owners, agents, and especially with the practical and energetic masters of merchant vessels of every description, to mutual advantage, and to the benefit both of the commercial marine and the naval service. Let us consider for a moment the working of the branch office established in the Maritime Exchange, New York, which Lieut. V. L. Cottman, U.S.N., during the few years that he has been in charge, has brought into a position of usefulness commensurate with the vast shipping interests of the great commercial metropolis of the United States: in a single year (1886–87) 6,739 vessels were visited, nautical information furnished to 83,345 masters of vessels and others, 10,397 pilot charts distributed, and 3,601 special detailed reports of marine meteorology forwarded for use in the preparation of the Pilot Chart alone, in addition to all the regular office work, of which this is but a small fraction. Let me illustrate on the screen one of the most important blank forms now issued, on which reports of marine meteorology are recorded.* These blanks are issued in pamphlet form, a year's supply being bound together, and each one is torn out as soon as filled, and forwarded by the first mail that leaves the ship at quarantine; if in a foreign port, it is forwarded by the United States Consul with his official mail. Other special blanks are also issued, but I cannot now refer to them further than to say that they are filled willingly and well on board vessels of every nationality. As soon as received at the branch offices, they are acknowledged and forwarded at once to Washington, to be used, first, in the preparation of the Pilot Chart for the coming month, and then in the compilation of the *Monthly Weather Review* and the *Summary and Review*, issued by the Chief Signal Officer, U.S.A. Thus the Hydrographic Office co-operates with the United States Signal Service by supplying meteorological observations taken at the same instant of absolute time on board vessels in every ocean; by means of such data the isobars and isotherms of the continents of the globe, drawn from data supplied by every nation, can be connected over the intervening oceans and plotted on the daily international chart, just as the corresponding lines are plotted each

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* Copies of these forms are issued herewith.

day on the daily weather map of the United States, from observations taken simultaneously at every signal station in the country.* The Signal Service, in return, furnishes from its great store of records such land observations as are needed from time to time to complete data necessary for the thorough study of some great cyclonic storm which has swept the coast, in order that we may learn from the lesson of experience to-day how best to shape our course to-morrow. Thus by earnest mutual co-operation mankind is slowly but surely falsifying the poet's lines—

> "Man marks the earth with ruin—his control
> Stops with the shore"

—and every year adds to the safety of navigation.

There is a widespread but erroneous idea that sailing vessels are being driven from the ocean by steam competition, and that comparatively few are being built: such is far from being the case, and it never *will* be the case. The sailing tonnage of the world is now nearly double that of steam, and this relative proportion is likely to be maintained. The commerce of the United States has had a glorious history in the past, it has survived many years of unfavorable circumstances, and it seems as though we can see the dawn of a new era of prosperity. In the words of Andrew Carnegie: "The shipping of the Republic ranks next to that of the world's carrier, Britain. No other nation approaches her in the race for place. In 1880, the carrying power of Great Britain was 18,000,000 of tons; that of the Republic, 9,000,000, being about one-half the motherland's commercial fleet, but more than that of France, Germany, Norway, Italy and Spain combined, these being the five largest carrying powers of Europe after Britain. The Western Republic has more than five times the carrying capacity of its European sister, France, and quite four times as much as Germany. Her ships earned nearly twenty per cent. of the total shipping earnings of the world in 1880. France and Germany each earned but a shade over five per cent. The first commercially successful steamboat navigated the Hudson, and the first steamship to cross the Atlantic sailed under the American flag from an American port."

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* The daily international chart was illustrated by means of a lantern slide and explained briefly.

With such a history, and with such a standing to-day in spite of the fact that the unprecedented internal development of the United States—agriculture, manufacture, railways—has for a time withdrawn capital and energy from that activity in ship-building and commerce which in the "fifties" was rapidly carrying us to the foremost place, it cannot be doubted that with the awakening of public interest to the need of such a national policy towards our commerce as our conditions and best interests demand, the American flag will again be a familiar sight in every port of the world, in many of which it is now almost unknown. Sir Walter Raleigh well said that "whosoever commands the sea, commands the trade of the world; whosoever commands the trade of the world, commands the riches of the world—consequently the world itself;" now as this is exactly what is, in the opinion of all good Americans, the "manifest destiny" of the United States, we may as well step in now and claim our inheritance, instead of leaving future generations to wonder at our short-sightedness.

In closing this brief review of the wide range of subjects that enter into the preparation of the Pilot Chart, any one of which is worthy the study of a lifetime, I would solicit the interest and kindly feelings of this audience towards the men who pursue the hazardous calling of a seafaring life, and for whose benefit and assistance the work of the Hydrographic Office is so largely devoted. From 5,000 to 6,000 lives are lost at sea each year. Not one of these cyclonic storms, whose tracks I have illustrated to-night, crosses the Atlantic without leaving new derelicts and drifting wrecks in its path, and adding new names to the long list of vessels that have left port never to be heard of more; and what a history of hardship, suffering and death could be written of each of these drifting wrecks, if the whole truth were known! The Hydrographer during the few years of his present tour of duty has succeeded in establishing branch hydrographic offices in our principal sea ports, where nautical information of every character is furnished to navigators free of all expense, and a most appropriate, useful and instructive field of duty offered to naval officers in time of peace. Cordial relations have been established with the mercantile marine, and the machinery of every department of the Government has been utilized to contribute to the safety and success of commerce. The Pilot Chart has been established, to

give early and accurate information regarding the work of each division of the office, and in many ways to lessen the hazards of the sea. In his enforced absence this evening, I feel that I may properly recall to mind that it is to his untiring energy that the perfection of every detail of this work is due. Believing that it is better to honor a man while he is living, rather than to wait for an opportunity to write his epitaph, I cannot close a lecture on the Pilot Chart better than by presenting on the screen the photograph of an old friend of yours, the pilot himself, Commander Bartlett.

THE ELECTRICAL DISTRIBUTION OF TIME.

By ALLAN D. BROWN, Commander, U. S. Navy, Assistant Superintendent of the Naval Observatory, Washington.

[*A Lecture delivered before the* FRANKLIN INSTITUTE, *January, 13, 1888.*]

Prof. EDWIN J. HOUSTON, in introducing the lecturer, said:

"The value of any system for the Electric Distribution of Time will necessarily depend on the accuracy of the time transmitted and the extent of the territory covered. I take pleasure in introducing to you Commander ALLAN D. BROWN, of the United States Navy, Assistant Superintendent of the United States Naval Observatory of Washington, D. C., who will explain to you the methods employed by the United States Government for the telegraphic distribution of time."

Commander BROWN spoke as follows:—

The subject upon which I have the honor to address you this evening is the Electrical Distribution of Time. Leaving out of consideration the question as to what Time is, what its measure and how obtained—questions the answers to which would of themselves serve as a subject for an evening's lecture—I will pass at once to a definition of the title which has been chosen for this address. By this title is understood the causing of the instant shown by a timepiece at a central station to be marked by some apparatus prepared to receive the necessary signal at another station in electrical connection with such central station.

If the apparatus at the receiving station is in the nature of a timekeeper, its operation must be automatic; and to secure the highest possible accuracy, the action of the central timepiece must likewise be automatic. In its best form, then, our title may be said to mean the automatic electrical synchronization of one or more clocks by a clock at a central station; with this synchronization may also be associated the registering of the signal upon a chronograph, the ticking of a telegraphic instrument, the firing of a gun, the ringing of a bell, the discharge of a flashing signal, or the dropping of a time ball; in a complete system any or all of these means will be used according to the circumstances of the case under consideration. It is essential, to insure the highest order of accuracy, that the central station shall always be at an astronomical observatory, and preferably at one which is able to devote the services of one or more persons to this special duty. Such work is known briefly as a time service, and its signals as time signals. A brief historical review of the evolution of the time service of to-day will not, it is hoped, prove uninteresting.

As early as 1816, one Ronalds, an Englishman, invented a telegraph which was so dependent upon timepieces for its working that it may be said to have been a device for the temporal distribution of electricity. He connected two clocks with some 500 feet of insulated copper wire; upon the seconds arbor of each clock was placed a circular plate of brass, the circumference of which was divided into twenty equal parts, the chief letters of the alphabet and a double series of numbers up to ten being placed in these divisions. In front of this was a second plate in which was an opening through which one letter and figure were visible; in front of this latter plate was suspended a pith-ball electrometer connected with the wire between the two clocks and also with a frictional electric machine; this apparatus was in duplicate, one for each end of the line. An electrical pistol was also in circuit when the apparatus was not in use, so that by its discharge the attention of the attendant would be attracted when desired. The manner of using this telegraph was as follows: The clocks were first supposed to be accurately synchronized, so that the same letter would appear at the same instant in both plates; the machine was turned and by the electricity thus generated the pistol at the other end of the line was discharged; the attendant in reply made a signal pre-

viously agreed upon, by waiting until this pre-arranged letter was in sight and then turning his machine, when the charge would cause the pith balls of the electrometer to diverge at both stations; the first operator would cause the discharge of the machine by a touch, the pith balls would fall together; the message would then be sent in like manner as each letter came in sight through the hole in the upper plate, the receiver noting each letter as the balls fell. There were two difficulties in the way of the use of this plan; (1) that of obtaining a current at all times; (2) the fact that it would be impossible to keep the two clocks always exactly together; this, however, could easily have been gotten over, as the sender could signal when a certain letter was visible, and the receiver noting the one he saw could then tell how much his clock was out of the way. In effect this was the first attempt at telegraphic time signals, and for this reason only is it here referred to.

In 1833, the German mathematician Gauss, associated with Weber, erected a line of telegraph some five miles in length, connecting the astronomical and magnetic observatories in Göttingen with various other stations. He obtained his current from a crude form of magneto-electric or dynamo machine and the whole apparatus was of a very unwieldy character; a flattened coil containing some 30,000 feet of iron wire had suspended within its centre a magnetized bar weighing some thirty pounds; upon the suspending wire was arranged a mirror in which was reflected a scale, the latter being viewed through a magnifying glass.

The dynamo had a pole changer so that the current could be sent in either a positive or a negative direction, and thus the bar be deflected either to the right or the left at the will of the operator; by a combination of these deflections a message could be spelled out. By this apparatus, as I have gathered, comparisons of clocks were actually made, and to these gentlemen is therefore due the honor of sending the first telegraphic time signals. Although no particulars of the way in which this Time Service was operated are on record, it may easily be surmised that the method was somewhat as follows: probably the hour selected for the signal was noon; two or three minutes before that hour by the standard clock, a signal would be sent over the line; as the hands of the clock marked the exact hour, one distinct deflection

of the bar would be made, at which instant the receiver would note the time shown by his clock; subsequently ascertaining the error of the standard, that of the other would readily be deduced.

In 1840, Mr. Charles Wheatstone announced the invention of an apparatus "enabling a single clock to indicate the same time in as many different places, distant from each other, as might be required." He proposed to accomplish this object by connecting electrically a standard clock with his *electro-magnetic clock*, which latter consisted "simply of a face with its second, minute and hour hands, and of a train of wheels which communicated motive-power from the arbor of the second hand to that of the hour hand in the same manner as in an ordinary clock train;" a small electro-magnet was caused to act upon a peculiarly-constructed wheel placed on the seconds arbor, in such manner that whenever the temporary magnetism was either produced or destroyed, the wheel (and consequently the second hand) advanced the sixtieth part of its revolution. On the axis of the scape wheel of the primary clock was placed a small disc of brass, which was first divided into sixty equal parts; each alternate division was then cut out and filled with wood, so that the circumference consisted of thirty alternations of wood and metal. A very light brass spring was secured to an insulator attached to the clock frame, its free end pressing upon the circumference of the disc; connection having been made between the insulated end of the spring and one end of the wire with which the electro-magnet was wound, the circuit was completed by the other end of the wire being connected to the clock frame through a battery; the primary clock being running, it followed that the circuit was made and broken each alternate second, while the distant dial recorded the advance of its wheel in unison with that of the parent clock. This is practically the same thing as the so-called electric time system of the present day, and it was the first attempt at the distribution of time by electricity. It had the defect common to all such systems of being applicable to only a limited space, and in addition it was subject to the same trouble that besets everyone who proposes to rely upon electricity derived from a battery as a motive-power for any sort of machinery; accidents *will* occur, and in a system of time distribution on this plan an accident is fatal to precision.

The completion of the Morse telegraph between Washington and Baltimore, in May, 1844, afforded the means for the next step in the evolution of our subject, and for this we are indebted to a naval officer, Commander Wilkes (afterward Rear Admiral), who, associated with Lieutenant Eld, transmitted time signals between the two cities. So keen was Wilkes in this matter, and so alive to its importance, that although the telegraph was not completed until the 27th of May, yet, on the 9th of June, Wilkes was exchanging his first signals, completing his work on the 12th. He used two chronometers, each rated to local time, and thus ascertained the difference of time between the two cities, and hence the difference in their longitude; his determination of this difference was only 3-100 second from that subsequently determined by the Coast Survey when more accurate methods had been devised.

Two years later, in October, 1846, time signals were exchanged between the Naval Observatory, in Washington, and the Observatory of the Central High School, in Philadelphia, this being the first use of what has since come to be known as the American telegraphic method of determining differences of longitude. This work was planned under the Coast Survey by Mr. Sears C. Walker, an assistant in that office. The observations were made by Prof. Kendall, in Philadelphia, and Lieutenant Almy, in Washington.

In July and August, 1848, signals were exchanged between the observatory of Harvard College and a private observatory in New York. During this work, Prof. Bond, of Harvard, conceived the idea of an automatic circuit interrupter to be worked by the clock used in the observations. He communicated his ideas to the Superintendent of the Coast Survey, and by him was authorized to construct a clock after his plans. This work was not finished until some time in 1850.

In the meantime Mr. Walker, in conversation with Prof. O. M. Mitchell and Dr. John Locke, of Cincinnati, had told them what the Survey desired in the way of an automatic registration apparatus. Both these gentlemen set at work, and Mitchell devised an apparatus which was finally completed in February, 1849. Locke busied himself in the same direction, and twelve days after his talk with Walker he had perfected his apparatus. In this each of the sixty teeth of a wheel on the seconds arbor of a clock struck the

arm of a tilt hammer. When the tooth was in a horizontal position, the other arm of the hammer fell upon a bed of platinum, which was in connection with one pole of a battery, while the fulcrum on which it moved was in connection with the other pole. The circuit was then broken and made at each rising and falling of the hammer. The next step was to connect the clock with some form of registering apparatus, and for this purpose the ordinary Morse register, with its continuous fillet of paper, was used. On the 17th of November, a little more than three weeks after the idea was first suggested to him, Locke had in operation his clock, registering its beats over the entire line between Cincinnati and Pittsburgh, a distance of more than 400 miles.

This was the first instance in which time signals were delivered *automatically*, by telegraph. As the fillet of paper passed through the register, a continuous record of the seconds was made, with nothing, however, to indicate the beginning of the several minutes; this indication was accomplished by the use of a break circuit key which the observer held in his hand, and pressing at the sixtieth second of each minute, caused the registration to cease for three or five seconds as might be desired, thus marking the beginning of the minutes. Presumably Locke was engaged during the following six weeks in perfecting his invention, for it was not until December 30th that he announced to Lieutenant Maury, the Superintendent of the Naval Observatory, what he had accomplished, and offering it not only for the telegraphic determination of longitudes, but also "as useful in a local observatory as a faithful and convenient register of observations" On the 5th of January, 1849, Maury replied in substance as follows: "I regard it as one of the most important inventions of the age. Feelings of professional pride give additional zest and warmth to these congratulations. For ages the problem of longitude has occupied the mind of wise men, and commanded the attention of governments. This discovery of yours is the crowning work in the great problem. Permit me to claim this high honor first for my country, and next for the navy. An American naval officer, Capt. Wilkes, was the first to apply the magnetic telegraph to the practical determination of longitude. It greatly lessened labor and refined results. The next and last step has been made by yourself, who also are an ex-officer of the navy. You have, by your invention, eliminated

from the problem the errors arising from comparing the face of one clock with that of another, and made it as easy and practicable to divide seconds into hundredths, as before it was to divide minutes into seconds. By your invention you enable the astronomer to make the ticks of his clock here in Washington to be heard wherever the telegraph leads, and you make the clock to divide those seconds into hundredths."

On the same day he addressed a letter to the Secretary of the Navy informing him of Locke's invention and recommending it in the highest terms. This letter was made public, and after some further correspondence it was followed by an invitation from the Secretary to Locke to come to Washington; the subject of an appropriation was discussed, and after much push on Maury's part the sum of $10,000 was put in the naval bill by the House, for the purchase of a clock on Locke's plan; this came very near being lost in the Senate, but it was saved by the exertions of the friends of the measure, and became a law on the 3d of March. By the provisions of the act the clock was to be erected at the Naval Observatory. This was done, and on the 7th of December, 1849, the clock, with the chronograph attachment was used, for the first time, and proved to be a great advance over the old method, although there was still some difficulty in the matter of accurate registration.

As before stated, in 1850, Prof. Bond, of Harvard Observatory, completed his clock for the Coast Survey, and in addition invented an improved chronograph in which the paper was placed upon a revolving cylinder, the driving power of which was so adjusted as to cause one revolution per minute to be made, the record being made by a pen in a continuous spiral line; but as in Locke's plan of the Morse fillet, there was no means of noting the beginning of each minute automatically. About the same time the cylindrical form was under consideration at Washington, but there were some difficulties which it does not appear were surmounted at this date.

In 1851, the Bond chronograph, with its ingenious driving machinery known as the spring governor, was taken to England and there exhibited, eliciting much commendation and receiving a gold medal at the Great Exhibition of that year. The Astronomer Royal, of the Greenwich Observatory, in his report for June, 1851,

states that he has adopted the plan of "making a galvanic register of transits in the American manner," but the cylindrical chronograph was not adopted until some three years later—a suggestion by Maury during a visit to Greenwich having enabled Sir George Airy to overcome the practical difficulties which were encountered.

During this same year, the observatory at Harvard was connected with the various telegraph lines from Boston, as many longitude operations were being carried on for the Coast Survey. In this manner the attention of such portion of the public as were interested in such matters was drawn to the practicability of obtaining accurate time from the observatory, and in many cases regular arrangements were made for the transmission of the signals throughout Massachusetts and some of the other New England States. Indeed, at present, the time service of Cambridge furnishes the chief source of comparison in that section of the country; the observatory of Yale College also possesses such a service, which supplies Connecticut in like manner. The observatory of the Washington University at St. Louis, and that at Alleghany, Pa., also have extensive time service; and there are others covering less ground.

At Washington the Naval Observatory has dropped a time ball since the first occupation of the completed buildings in 1844, following the example set at Greenwich, eleven years earlier. At first the dropping was done by hand, upon signal received from the chronometer room; later this signal was sent electrically and the dropping of the ball was performed automatically by the same signal. This ball served to give the moment of noon not only to the cities of Washington and Georgetown, but also to the Navy Yard and to such vessels as happened to be lying there. No telegraphic signals were transmitted, however, for several years, the Royal Observatory at Greenwich far outstripping us in that respect, as a system of time signals to the important cities and towns of England was in operation as early as 1852. This, of course, was readily accomplished in a country of such small extent, where the difference of any given local time from that of Greenwich is not great; but in our own case, the great extent of longitude and the different local times kept through what was supposed to be the necessity of the case, conspired to prevent the extension of any such

system. Local jealousies had also a part to play in the matter, as the railroads running out of Boston would not keep New York time, and *vice versa.*

With this brief retrospect of the course of events which has made the electrical distribution of time possible, let us return to the subject proper of this essay; and in so doing I beg leave to repeat a portion of the definition with which it began, viz: "By the electrical distribution of time is understood the causing of the instant shown by a timepiece at a central station to be marked by some apparatus prepared to receive the necessary signal at another station in electrical connection with such central station. It is essential, to secure the highest order of accuracy, that the central station shall always be at an astronomical observatory, and preferably one which is able to devote the services of one or more persons to this special duty." In order to a fuller understanding of the functions of an observatory, it will be necessary to call your attention to some of your early instruction in astronomy. The interval between two successive transits, or meridian passages, of the sun, is an apparent solar day; owing to the unequal motion of the earth in its orbit (or to put the statement in another form, to the apparent unequal motion of the sun in the ecliptic) two successive apparent days are not of the same length. As a constant standard of time is necessary, it has been found essential to assume an imaginary sun moving in the equinoctial (or the plane of the earth's equator) at a uniform rate, which is the mean rate at which the true sun moves in the ecliptic; the interval between two successive transits of this imaginary mean sun is a mean solar day, and in a clock keeping mean time, the hands would (if the clock were correct) point to $12^h\ 0^m\ 0^s$ at the instant of transit, which is known ordinarily as NOON. As a matter of fact, however, the sun is rarely used at observatories for the determination of time, but stars are employed instead; this is done, not only because the tables of the positions of the stars are more accurate, but because several stars can be observed at about the same time and the results deduced from these observations made to serve as checks upon each other. The interval between two successive transits of the same star is called a sidereal day; this interval is constant, and is (like the mean solar day) divided into twenty-four hours. Each star comes to the meridian at an earlier period than on the day preceding, if

the transit be noted by a mean time clock; the difference between a star and a sidereal day is 3^m 56^s 56, and hence the sidereal 0^h is constantly getting ahead of the solar 0^h, so that it is always necessary to reduce the *sidereal* time found by the star observations to that used in ordinary life, or to *mean* time. The positions of stars are given in the tables by their *declination* (similar to terrestrial latitude) and their *right ascension* (similar to terrestrial longitude); the right ascension of the star being reckoned from the celestial prime meridian, it follows that when any given star crosses the meridian, the sidereal clock should show the time given in the table as the right ascension of such star; the difference between the time actually shown by the clock and this right ascension is the error of the clock; comparing then the time shown by the sidereal clock with that shown by the mean time clock, we find the error of the latter. This is briefly the method followed by all observers, and hence is common to all systems of time signals. We have, then, as essentials of any such system, (1) an instrument for observing the transits of stars; (2) a sidereal clock, and (3) a mean time clock. This mean time clock (like all timepieces) will not run accurately, its rate varying, being sometimes less and sometimes greater; the pendulums of such clocks are generally very well compensated for changes of temperature, but it has been found that the density of the air has a decided influence upon the rate at which the clock runs; when the barometer is high, the clock loses on its rate, gaining when it is low. In order, then, that the time which is sent out over the wires should be correct, it is necessary either to have some arrangement for correcting the standard mean time clock so as to make it correct, or else to have a similar clock which can be likewise corrected; such a clock is known as a transmitter.

The system of the Greenwich Observatory being the oldest in point of time merits the first description. The standard sidereal clock is a remarkably fine piece of workmanship, having in addition to a peculiarly constructed compensated pendulum, an auxiliary apparatus intended to still further aid in the compensation for changes in temperature, which it would be impossible to describe intelligibly without a drawing. There is also an arrangement for counteracting the influence of the variations in the density of the air, which is the invention of Sir George Airy, and

is very ingenious; two bar magnets are secured to the bob of the pendulum diametrically opposite each other, one with the north pole down, the other with same pole up; below these at a distance of about four inches is a horseshoe magnet which hangs on one end of a walking-beam, to the other end of which is attached a float resting on the surface of the mercury in the cistern of a specially-constructed barometer; with a rise in the barometer the horseshoe magnet rises nearer the bob and thus exerts a stronger influence upon the swinging magnets, causing the pendulum to oscillate more rapidly; the contrary takes place when the mercury falls. Notwithstanding all these refinements the published records of the observatory show that the clock does not run with perfect accuracy, a variation of its daily rate as large as 1·15 seconds being recorded in a year. It does, however, run with but slight variations of rate from day to day; still it shows as great a loss as one minute in six months; it is supposed to be regulated to lose a small amount daily, but the records show that it occasionally gains as much as half a minute in five or six months. I mention this here in order to show you that those people who talk about their clocks or watches running to within a few seconds a year are probably somewhat wide of the truth. This standard sidereal clock registers its beats upon the chronograph used in observing transits, controls the remaining sidereal clocks in different rooms of the building and finally drives (in unison with itself) a sidereal chronometer. The controlled clocks are upon the Jones' system (as modified by Sir George Airy); in this system the secondary clocks are required to be quite as good timekeepers as the primary one, which makes it too expensive for general use among the public. As used at Greenwich, the standard clock closes a circuit in which the controlled clocks are placed, every second; on the pendulum of each of these latter is a magnet, which at the end of its swing enters a coil of insulated wire; as the current passes the effect is to hold the magnet within the coil, and hence to place the pendulum in a definite position, which corresponds in effect to that of the pendulum of the primary clock; this closes the circuit by means of a wheel on the seconds arbor, which presses upon a spring at each forward motion. The sidereal chronometer already spoken of in this connection, is constructed practically upon the same principle as those of Wheat-

stone, referred to in the early part of these remarks. This sidereal chronometer is in the time service room and is used for the purpose of comparison with a similarly-constructed mean time chronometer which is driven by the mean time clock now to be described; this is essentially a galvanic clock of peculiar construction, and of which I imagine there are but few existing; as the pendulum swings to the right it closes a circuit through the coils of an electro-magnet which actuates a peculiar mechanism, by which, as the pendulum swings to the left, a weight is caused to impinge upon the pendulum, thus giving it the impulse which in an ordinary going clock it receives from the weight or spring; this impulse is given at each alternate vibration. At each extremity of the swing of the pendulum it closes a circuit which, acting upon the coils of two electro-magnets, alternately attracts and repels the opposite ends of a balanced polarized armature; this rocking motion is readily converted into a rotary one, causing the seconds hand to revolve, and, by the usual device of a train of wheels, the minute and hour hands also; there are several clocks driven by this pendulum, including the mean time chronometer just mentioned as being in the time service room. The apparatus for correcting the error of the standard mean time clock consists of a magnet secured to the pendulum which swings over a hollow coil of insulated wire attached to the clock case; if a current be passed through the coil in one direction the magnet on the pendulum is attracted and the oscillations are more rapid; if a current be sent in the opposite direction the contrary is the case; a switch in the time service room serves to operate this arrangement when desired, and the battery is so arranged that it will accelerate or retard the pendulum at the rate of one-tenth of a second in a minute. The practical working of the observatory portion of the time service is as follows: The error of the standard sidereal clock is obtained by means of star observations as before described; at 9 A. M. daily, the mean time and sidereal chronometers in the time service room are compared by what is known as the eye and ear method; that is to say, the observer waits for the coincidence of the beats of the two instruments and notes the time shown by each at this instant; applying the error of the sidereal clock to the time shown by the sidereal chronometer, the correct sidereal

time is found; by a comparatively simple operation the corresponding mean time is found, and from this the error of the mean time chronometer, or what is the same thing, the error of the standard mean time clock; suppose that this clock is found to be one second slow; the switch to the coil in the clock is turned in the accelerating direction for ten minutes, during which time the pendulum is swinging faster than usual, and at the end of this period the clock has gained the necessary second; and not only the standard, but all the clocks that are driven by it. In this condition the standard is in readiness to be used as a transmitter; it is in a circuit which is closed automatically every hour by the operation of wheels within the clock itself. The closing of this circuit operates a relay which transmits a single beat (that of 0 minutes and 0 seconds of the exact hour), to the General Post-Office in London, and also to the station of the railway leading to Deal. At this latter point a time ball is erected and is dropped by the hourly signal sent at 1 P.M. The hourly signal is also transmitted over certain private wires belonging to various jewelers, for the purpose of comparing their timepieces. In one case, at least, this signal is also used for purposes of distribution, as will be noted further on. The line to Deal is for a short time virtually under the control of the observatory, so that a return signal is sent which announces the fall of the ball. A very ingenious adaptation of the galvanic clock described as the mean time standard is in use on this circuit. At a certain point where the line to Deal is looped in, this second clock is placed. It is regulated so as to have a gaining rate of several seconds, so that at 1 P.M. it is always too fast. When that hour is shown by the clock, the circuit which operates the electro-magnet and thence the clock train is switched out automatically, and the Deal loop is switched in, the pendulum continues to swing until the passage of the signal from the observatory opens the circuit and the clock then moves on, showing the exact Greenwich time as it starts.

(*To be continued.*)

On SOME EARLY FORMS of ELECTRIC FURNACES.

No. 7. SIEMENS' ELECTRIC FURNACE or CRUCIBLE.

By Prof. Edwin J. Houston.

In 1879, Charles William Siemens took out letters-patent in Great Britain for "Improved Means and Apparatus for Producing Light and Heat by Electricity." This patent is numbered 2110 of 1879. The completed specification is dated November 26, 1879.

The matter contained in this patent, is, to some extent, an application of the principle described in a prior patent, No. 4208 of 1878, to the same inventor. This principle consists briefly, in cooling one of the electrodes of an electric source, by means of a stream of water forced through a cavity in the same.

Siemens applies this principle to the utilization of the direct heat of the voltaic arc for the heating of a crucible, in which furnace operations that require great heat may be conveniently carried on.

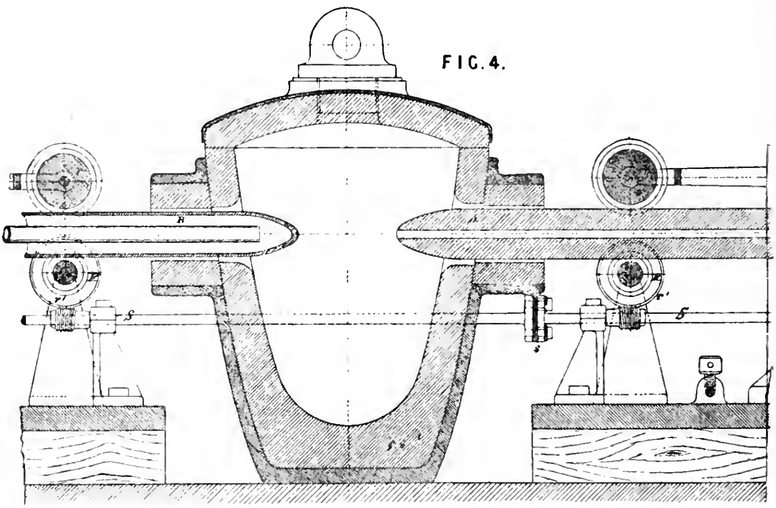
The following general description of this process is taken from the provisional specification, viz:

"In applying the electric current to the production of intense heat for the fusion of refractory substances, I employ two carbon rods, fitted to slide towards each other horizontally, within water-cased tubes, which are attached to the opposite sides of a crucible made of highly refractory material, such as lime or alumina, also water-cased if necessary. The substance to be fused is introduced into the crucible, and the carbon rods are advanced sufficiently near to each other to form the voltaic arc within the crucible. The clockwork which advances them has a flyer which can be retarded or arrested by a brake or stop connected to a thin metal strip which forms a part of the electric circuit, or to the armature of an electro-magnet, the coil of which forms part of the circuit. As the heat in the crucible increases, the resistance to the voltaic arc within it diminishes, and consequently the arc can be elongated, a result which results from the automatic retardation or stoppage of the feeding clockwork. The crucible may be closed by a cover

having apertures through which air or other gases may be blown or drawn to act on the substance under treatment. In some cases, instead of employing carbon for the terminals, they may be made of the material that is to be fused, when it has sufficient conductivity."

It will be noticed that the electric furnace of Siemens does not differ, in its essential features, from the earlier forms described by Depretz in connection with his experiments on the fusion of refractory substances, except that in some of Depretz's forms the voltaic arc did not play directly on the material subjected to fusion, but heated to intense incandescence the carbon crucible or vessel in

FIG. 4.



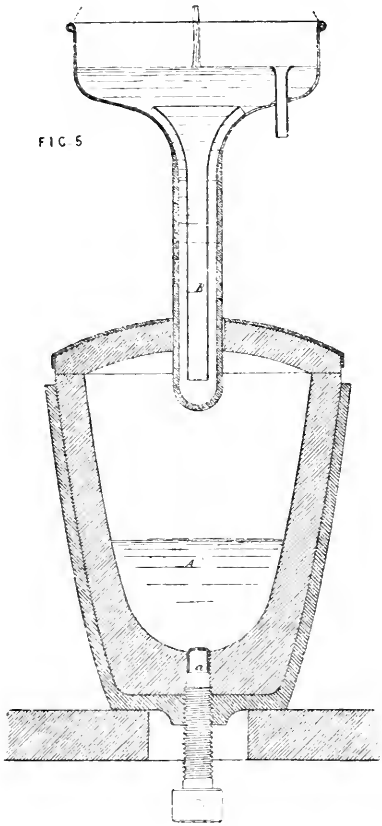
which said substance was placed. Depretz's furnace, however, provided no means for cooling the ends of the electrodes.

Siemens' furnace was not merely a crucible in which the fusion of highly refractory substances was accomplished. The hollow carbons, or the perforated cover, provided for the introduction of air or other gas, clearly shows that he contemplated the carrying on of what might properly be classed as furnace operations, or reductions, under the influence of the high temperature of the voltaic arc.

The forms of electric crucibles devised by Siemens will be best understood from the following description taken from the com-

pleted specifications, viz: "*Fig. 4* shows apparatus according to my invention for applying the heat of the voltaic arc within a crucible." * * * "I have shewn in the Figure one of the terminals *A*, to be a carbon, and the other *B*, as a metal pole cooled by circulation of water as described in the specification above referred to. Both terminals might, however, be carbons, and both

FIG. 5



or either might be tubular, as shown with respect to *A*, so that currents of air or other gas might be sent through them into the crucible for effecting chemical reactions therein. The terminals rest on grooved rollers *R*, *R*, being pressed down thereon by heavy rollers *r*, *r*." * * * * * *

"When the material treated in the crucible is a conductor, the arrangement shown in *Fig. 5*, may be adopted. In this connection

material A, such as fused metal forming the one terminal, lies in the bottom of the crucible in contact with a screw or pin, a, faced with the platinum or other metal that will not be acted on by the material A. The other terminal B, which is cooled by the passage of water through it, as described in the specification above referred to, is suspended through a hole in the crucible cover, and it can be made to ascend or descend as required for regulating the distance between the terminals, by the action of a solenoid or expanding metal wire or strip as described above with reference to the carbons of electric lamps."

In the operation of this crucible it was found that there was a tendency of the voltaic arc to pass to the walls of the crucible, rather than to the substance subjected to the heat. This tendency was, to a great extent, checked by surrounding the outside of the crucible with a coil of wire.

Some experiments conducted with this crucible by Dr. Siemens and Prof. Huntington, are recorded in a paper read by them at the fifty-second meeting of the British Association for the Advancement of Science, held in August, 1882.

The following abstract of some of the more interesting of these experiments is here given.

The current employed, which was of from 250 to 300 ampères, was obtained from five dynamo-electric machines, four of which were coupled together, and the other was employed as an exciter.

A number of difficult fusions were effected, viz:

(1) Six pounds of wrought iron were kept in the heat of the arc for twenty minutes and then poured into a mould. The cooled metal was found to be crystalline and to no longer possess the ability to be wrought.

(2) Twenty pounds of steel were completely melted in one hour in a single charge.

(3) Three-fourths of a pound of copper, placed in carbon dust, were melted in half an hour—only three-fourths of an ounce, however, was found remaining in the retort. The rest had been vaporized!

(4) One-quarter of an hour was sufficient to reduce eight pounds of platinum to the liquid state.

(5) Some curious results are noticed both during the fusion and vaporization of tungsten, and in the properties of the product as found in the electric crucible.

The electric crucible, as constructed by Dr. Siemens, must be regarded as admirably suited for investigation on the fusion of refractory substances.

CENTRAL HIGH SCHOOL,
PHILADELPHIA, *April 5, 1888.*

CHLOROPHYL AND GELATINE-BROMIDE PLATES.

BY FRED. E. IVES.

[*Read at the Stated Meeting, Wednesday, April 18, 1888.*]

The isochromatic processes now most used are incapable of producing correct monochrome photographs of objects in all colors; eosine and erythrosine plates are insensitive to red, and even cyanine plates will not show any difference between a black and a deep red without greatly over-exposing orange and yellow. The original process (collodion emulsion with chlorophyl) is the only one yet published which has not this defect.

But most photographers do not like to use this process, because suitable chlorophyl cannot be procured at all times, nor preserved without considerable loss of sensitiveness, and the plates must be prepared immediately before use, and exposed wet, in a strong light. Many who have seen the beautiful results obtained with this process have lamented the fact that chlorophyl could not be applied successfully in the gelatine plate process, and I tried many times to accomplish it. On several occasions, I obtained considerable color-sensitiveness, but the result was so uncertain as to be puzzling and discouraging. At last, however, I have succeeded in securing, by a surprisingly simple procedure, the full action of chlorophyl upon commercial gelatine-bromide plates.

The degree of color-sensitiveness obtained appears to bear a definite relation to the general sensitiveness of the plate employed, which should, therefore, be of the most rapid kind. They are prepared by flowing with the alcoholic solution of chlorophyl, *then drying* rapidly, *then soaking in water* for at least five minutes, after which they may be used at once. With two-year-old chlorophyl (obtained from suitable leaves, at the proper season, and

preserved with zinc powder in the solution), the absolute color-sensitiveness is fully equal to that of commercial "orthochromatic" plates, and is so distributed as to be capable of giving far more accurate results; but the blue-sensitiveness, which is reduced by cyanine and erythrosine, is actually increased by chlorophyl, making it necessary to use an extra deep orange color-screen with these plates. This excessive blue-sensitiveness is, in fact, something of an objection to the plates, because it is not easy to get a color-screen that cuts off just the right amount of blue light. With screen and exposure that would be exactly right for the commercial "orthochromatic" plate, the chlorophyl plate would be far over-exposed, with five or ten times too much action in the blue and violet. But if the color-screen is deep enough, the resulting negative is perfect for all colors.

For purpose of comparison, I have made one photograph of the solar spectrum on a very rapid gelatine-bromide plate treated with chlorophyl, and another on a commercial "orthochromatic" plate. A yellow screen was used to reduce the action at the violet end of the spectrum, and both plates received the same exposure. The total amount of action below the Fraunhofer line *E* is about the same in both plates, but in the commercial "orthochromatic" it is mostly confined to the yellow, while in the chlorophyl plate it is pretty evenly distributed throughout the yellow-green, yellow, orange and red, down to the Fraunhofer line *a*.

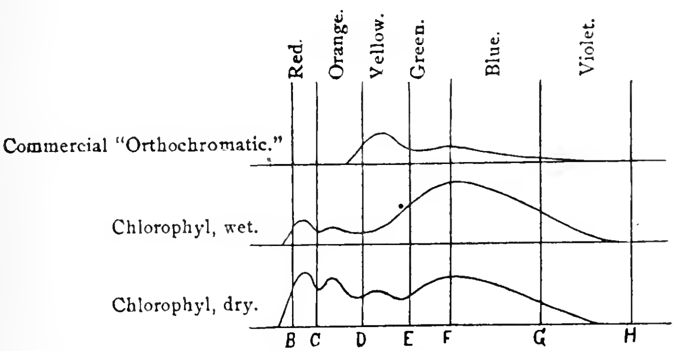
In view of the fact that chlorophyl has been tried with gelatine-bromide plates a great many times, and in various ways, without definite success, the most surprising thing about this method is its simplicity.

Since obtaining these results, I have read a very interesting paper by Capt. Abney, in which he calls attention to the fact that cyanine and erythrosine will impart color-sensitiveness to a commercial gelatine-bromide plate when merely applied to the surface, as by flowing the plate with collodion or varnish in which a little of the dye is dissolved. He concludes that contact of the dye with the surface molecules of bromide of silver in the plate is all that is required to secure color-sensitiveness, and suggests that chlorophyl should therefore succeed with gelatine-bromide plates if merely applied in that way, or in alcoholic solution. It

will not; the subsequent soaking in water is essential to the production of color-sensitiveness.

LATER EXPERIMENTS.

Since the above paper was read, exposures have been made upon dried plates, with the following results: The color-sensitiveness proved to be about three times greater than before drying, and the blue sensitiveness considerably less. The dried plates invariably fogged, and it was necessary to use a brush to prevent the formation of air bells and force an even action of the developer.



Action of solar spectrum on commercial orthochromatic and two-year-old-chlorophyl gelatine-bromide plates, through light yellow color-screen.

EXPERIMENTS WITH ERYTHROSINE AND CYANINE.

The discovery that chlorophyl would act so well when applied in the above-described manner, suggested the idea of trying other color-sensitizers in the same way. Plates were therefore prepared with erythrosine, by flowing with alcoholic solution,* then drying, then washing or soaking in water. The result was a great surprise. Although not a trace of ammonia or silver were used, the plates showed several times more absolute color-sensitiveness than the dried chlorophyl plates (but all in the yellow and green), and about ten times more than the commercial orthochromatic plates. They work clear and brilliant, and are sensitive enough for portrait work with the yellow screen.

Cyanine was then tried in the same way, and gave even more remarkable results than erythrosine. Without reducing the blue sensitiveness in the least, it made an extra rapid plate as sensitive

* Erythrosine, 1 gr.; alcohol, 4 oz.

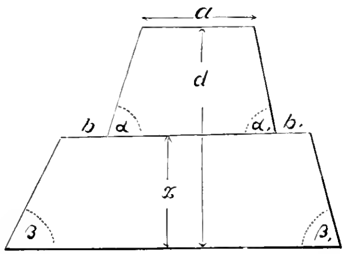
to the orange-red, orange and yellow of the spectrum as to the blue, and as sensitive to the green as to the violet. The absolute color-sensitiveness is many times greater than was ever before produced by cyanine, and ten times greater than has been produced by chlorophyl. The first plates that were prepared in this way gave only a mass of fog; the successful plates were washed and developed in total darkness.

One very important fact, discovered in the course of these experiments, is that the action of the dyes, by whatever method applied, is at least three times greater on some commercial plates than on others. The best plates I know of, have a full allowance of bromide of silver, in a very thin film of gelatine.

The MOST ECONOMICAL CROSS-SECTION of COMPOUND DIKES.

By L. d'Auria.

[The present paper refers to those stone dikes with a superstructure of concrete or crib work. The problem which the paper implies was proposed to the writer by Mr. L. Y. Schermerhorn, C.E.]



Let a represent the width at the top of the superstructure; b and b_1 the width of the bermes left at one side and the other of the foundation; d the total height of the section of the dike; α and α_1 the inclinations of the sides of the superstructure, and β and β_1 the inclinations of the sides of the foundation with the horizon; A, the cost per cubic foot of superstructure, and B, the cost per cubic foot of foundation.

The problem which is proposed to solve, consists in determining the height x of the foundation in manner, so that the cost of the dike will be a minimum.

The width at the top of the foundation is evidently

$$a + b + b_1 + (d - x)(\cot \alpha + \cot \alpha_1),$$

and the width at the bottom of the foundation is

$$a + b + b_1 + (d - x)(\cot \alpha + \cot \alpha_1) + x(\cot \beta + \cot \beta_1).$$

Taking one-half of the sum of the two, we obtain the mean width of the foundation, viz:

$$a + b + b_1 + d(\cot \alpha + \cot \alpha_1) - \frac{x}{2}(2 \cot \alpha + 2 \cot \alpha_1 - \cot \beta - \cot \beta_1).$$

Multiplying by x and by B, we have the cost per linear foot of foundation, viz:

$$B x \left[a + b + b_1 + d(\cot \alpha + \cot \alpha_1) - \right.$$

$$\left. - \frac{x}{2}(2 \cot \alpha + 2 \cot \alpha_1 - \cot \beta - \cot \beta_1) \right].$$

The mean width of the section of the superstructure is

$$a + \frac{d - x}{2}(\cot \alpha + \cot \alpha_1),$$

which, multiplied by $(d - x)$ and A, gives the cost per linear foot of superstructure, viz:

$$A(d - x)\left[a + \frac{d - x}{2}(\cot \alpha + \cot \alpha_1) \right].$$

Adding this to the cost per linear foot of foundation, and putting equal to zero the first *derivate* of the sum with respect to x, we find

$$x = \frac{(A - B)[a + d(\cot \alpha + \cot \alpha_1)] - B(b + b_1)}{B(\cot \beta + \cot \beta_1) - (2B - A)(\cot \alpha + \cot \alpha_1)}.$$

Putting $\frac{A}{B} = n$, will be found

$$x = \frac{(n - 1)[a + d(\cot \alpha + \cot \alpha_1)] - (b + b_1)}{\cot \beta + \cot \beta_1 - (2 - n)(\cot \alpha + \cot \alpha_1)}.$$

When the superstructure is rectangular, as in the case of cribs,

then $\cot \alpha = \cot \alpha_1 = o$, and

$$x = \frac{a(n-1) - (b + b_1)}{\cot \beta + \cot \beta_1};$$

and when the bermes are equal and $\beta = \beta_1 = 45°$, then

$$x = \frac{1}{2} a n - \frac{a + 2b}{2} \qquad (1)$$

In the report of the Chief of Engineers of the U. S. Army, of 1887, p. 2407, Major M. B. Adams, with a direct analysis applied to this last case, finds,

$$= \frac{c}{2 l c^1} - \frac{a + 2b}{2} \qquad (2)$$

in which c is the cost of one hemlock course and its stone filling above grillage, whose length is l, and c^1 is the cost of one cubic foot of foundation. Now, observing that $c = A\,a\,l$ (in which A is the cost per cubic foot of crib), and that $A \div c^1 = n$, equations (1) and (2), after the substitution, will be found to be identical.

Since $a + 2b$ represents the width at the top of foundation, we can denote this width by f, and write

$$x = \frac{1}{2}(a n - f),$$

which is very simple to remember and can be applied readily as a test to dikes already built.

GENERAL THEORY OF JOINTED BOW GIRDERS.

By E. A. Werner, C.E.

(*Continued from Vol. cxxv, page 409.*)

ERRATA.

Note.—Correct in Part I, of this paper, the following errors:

Page 391, line 7 from top, *read*—

$$V_m = Q - G_1 \text{ instead of } V_m = Q - g_1$$

Page 394, *read* equation 12—

$$\frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f} \text{ instead of } b = \frac{2fx + ly}{2fl} = \frac{\zeta + y}{2f}$$

Page 396, line 13 from top, *read*—

$$\zeta \gtrless y \text{ instead of } \zeta \lessgtr y$$

the same sums with regard to the external forces—the loads and the reactions of the abutments.

These equations give the internal forces of the removed part as functions of the external forces, which have been developed in the first part.

The above equations express quite generally the conditions, which must be fulfilled in any structure, regardless of form, system, loading, or number of supports used.

As there are only *three* equations we deduct, that, without more or less arbitrary assumptions, not more than three unknown quantities or forces can be defined in any section of a structure.

The structures intended to resist the forces represented by the above equations must be able to take up horizontal and vertical

then $cot\ \alpha = cot\ \alpha_1 = o$, and

$$x = \frac{a(n-1) - (b + b_1)}{cot\ \beta + cot\ \beta_1};$$

and when the bermes are equal and $\beta = \beta_1 = 45°$, then

$$x = \frac{1}{2}\ a\,n - \frac{a + 2\,b}{2} \qquad (1)$$

In the report of the Chief of Engineers of the U. S. Army, of 1887, p. 2407, Major M. B. Adams, with a direct analysis applied
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GENERAL THEORY OF JOINTED BOW GIRDERS.

BY E. A. WERNER, C.E.

(*Continued from Vol. cxxv, page 409.*)

PART II.—INTERNAL FORCES OR STRAINS.

A.

LATTICE GIRDERS.

As we know from the first part, the equations expressing the equilibrium of the forces in the structure are those of a free, rigid system, or if we refer the system to a rectangular system of co-ordinates:

$$\Sigma\,(x) - H = 0$$
$$\Sigma\,(y) - V = 0$$
$$\Sigma\,(x\,y) - M = 0$$

wherein:

$\Sigma\,(x)$, $\Sigma\,(y)$, $\Sigma\,(x\,y)$ represent the sums of all the forces in the direction of the X and Y axis and their moments, H, V, M, the same sums with regard to the external forces—the loads and the reactions of the abutments.

These equations give the internal forces of the removed part as functions of the external forces, which have been developed in the first part.

The above equations express quite generally the conditions, which must be fulfilled in any structure, regardless of form, system, loading, or number of supports used.

As there are only *three* equations we deduct, that, without more or less arbitrary assumptions, not more than three unknown quantities or forces can be defined in any section of a structure.

The structures intended to resist the forces represented by the above equations must be able to take up horizontal and vertical

forces and their moments,* and if we remember, that a moment can be taken up in its plane at any point, the same as the point of application of a force can lie in any point in the direction of the force, we see that the stiffening structure, as is called the structure taking up the effect of the moments, can lie anywhere in the bow girder and that a great variety of forms and systems will come under the above equations.

Accordingly as a separate stiffening structure is used or not, we shall have:

(1) A *slack* bow, the stiffening structure forming a separate structure or truss.

(2) A *stiffened* bow, the stiffening structure being connected with the bow struts.

NOTE.—Generally a subdivision of the stiffened bow is called "stiffened gusset," when the stiffening structure fills the gusset between the bow and the road.

Still as the way to take up the moments is completely arbitrary, we can as well use two or more stiffening structures and have thus a *third* great subdivision:

(3) Partially stiffened bow and partially stiffened roads. The stiffening is then scattered over the bow struts and a special stiffening structure.

Moreover, any bow can be used as a "beam" having *only* vertical and *no* horizontal reactions, by tying together both abutment joints with a string taking up the horizontal thrust of the abutments. We have then:

(4) The *bow beam*, and any one of the above systems may be used in the bow beam.

But if the stiffening structure is connected with the string, some more very useful combinations are brought forth. They are called *bow beams with stiffened strings*, and comprise the following combinations:

(*1*) The string forming the lower chord of the stiffening structure.

(2) The string forming the upper cord of the stiffening structure.

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* As is known, the faculty to take up horizontal forces is the deciding characteristic of bow structures, but not every structure taking up horizontal forces is a bow structure, as we shall see later.

In both cases, if the bow structure has only negative or positive moments, the stiffening structure can have *two* tension chords and no compression chord, provided the stiffening structure is so disposed as to have the strains from the thrust in the respective chord of the stiffening structure greater always than the compression strain from the moments.

(3) The stiffening filling the space between the string and the bow strut.

These structures look much like ordinary beams, having only joints on top. These are the most used forms of the bow structures. Other variations may yet be found in combining the above forms, but howsoever this may be done, the structure will consist either of *separate parts* taking up separately the horizontal and vertical forces and moments, or of *one* structure taking up all the forces at once, and accordingly as the first or second arrangement is selected the expression of the forces acting in the members will be different. But whether we select a structure with separate stiffening girder, or a stiffened bow structure, in applying the general equations of equilibrium to it, the resulting expressions will contain besides known quantities on one side:

[the strains in the members] on the other [y_m^0 y_m' y_m''] the quantities expressing the form of the structure and, accordingly as one or the other of these groups of quantities is assumed to be known, we shall have *two* quite different problems to solve :

I. The form of the structure being given, to find as functions of the external forces (loads and abutment reactions).

(1) The forces acting in the members ; and,

(2) The maximal and minimal values of these strains and the rules governing them.

II. The forces (strains) in the members of the structure with their maximal and minimal values being known, also the laws governing them, to determine the form of the structure so as to answer certain special conditions.

The solution of problem II gives the means on hand, by using special appropriated forms, to keep the values of the strains acting in certain members inside of certain limits, or to alter to a certain extent the laws governing these strains, but this problem II can evidently not be solved without the knowledge of the strains expressed as functions of the loads and the rules governing the maximal and minimal values of these strains.

I thus begin with the first problem :

I. *The form of the structure being known, to find:*

(*1*) *The strains in the members as functions of the external forces.*

(*2*) *The maximal and minimal values of these strains and the positions of the loads inducing them.*

In this case $y_m{}^0$ $y_m{}'$ $y_m{}''$ are known quantities, the figure of the structure being given *a priori.*

The structures themselves can consist, regardless of form or system, of:

I. Structures with open web (lattice).

II. Structures with full web (plate), and this so, that either one kind, or in case of several parts forming the bow, both kinds combined, are acting and the way of developing the equations, expressing the forces acting in the different parts, will necessarily be different accordingly as lattice or plate girders are selected.

I will begin in developing the equations, when the structure consists of:

LATTICE GIRDERS.

In these girders, in opposition to girders with full web, the material is massed in single members.

In these girders it is always assumed :

(1) That the deformation of the whole system is so slight, that it can be neglected, especially so slight that the length of the members and the angles between them are not materially affected.

(2) That the resultings of the forces of the different members intersect *mathematically* in points, the *panel points.*

(3) That the loads are taken up in the panel points.

(4) That the exact length of h = depth of the stiffening truss is used.

This depth is as known:

$$h = \frac{\text{Moment of Inertia}}{\text{Statical Moment}} \text{ of the section.}$$

If these assumptions are not mathematically fulfilled, supplementary strains will be generated in the members, of which the following theory gives no account and which will greatly alter the result or even make it completely wrong.

In lattice girders evidently the longitudinal members must take

up the thrust. But the way this is done is completely arbitrary. It depends upon many factors, as location, the form of the structure, etc.

I will first assume that *one* member always takes up the thrust completely and fully. If the thrust is taken up completely and fully by one member, this member has the form of the line of thrust. If the thrust is scattered over several members, the line

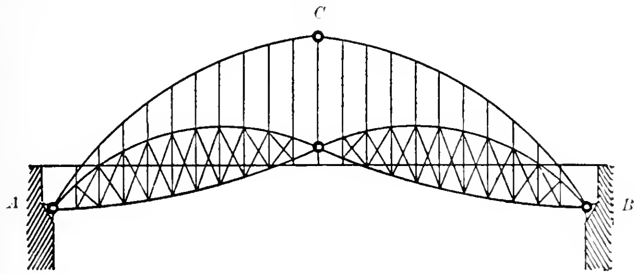

FIG. 1.

of thrust is the locus of the points of application of the thrust in the structure.

The above assumption still leaves it an open question how the moments are taken up. But in looking over the forms and ways already enumerated previously, we see that only *two* distinct divisions exist: a slack and a stiffened bow, and the equations expressing the forces acting in the members of these two kinds of structures will answer also for all combinations.

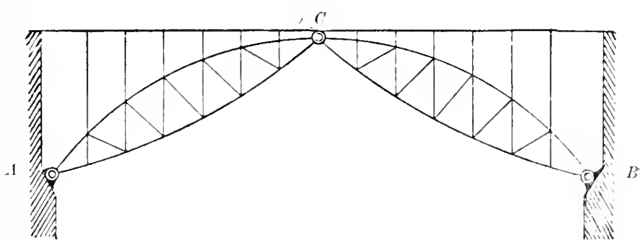

FIG. 2.

Fig. 1 represents a slack bow and a separate stiffening structure. *Fig. 2*, a stiffened bow.

In the slack bow, according to our assumption, the bow strut $A\ B\ C$ takes up all the thrust and has the form of the line of thrust. In the stiffened bow, I will assume, as it does not matter which chord is selected, that the *upper one* takes up the whole

thrust and has the form of the line of thrust. In both structures a section be made in the mth panel, infinitely near the mth panel point, and the members and the forces acting in it be called as follows:

$$\left.\begin{array}{r l} A = & \text{lower chord} \\ T = & \text{upper chord} \\ N' = & \text{tie} \\ N'' = & \text{counter tie} \\ P = & \text{post} \end{array}\right\} \text{ of the stiffening truss;}$$

$E =$ suspension member;
$B =$ suspended abutment, or suspension member of the top joint;
$D =$ bow strut;
$g =$ loads taken up in the panel point;
$U =$ horizontal component of the chord strain;
$u =$ abscissa of the maximum line of G_2 for U;
$W =$ horizontal component of the strain in the ties;
$w =$ abscissa of the maximum line of G_2 for W;
$p =$ abscissa of the maximum line of G_2 for P;
$\Delta x =$ panel length;
$\alpha', \alpha'', \beta, \gamma, \mu =$ angles of the members and strains N', N'', T, A, D with the x axis;
$\rho =$ angle of A or T with the X axis.

These angles always measured as acute angles.

$y^o\ y'\ y'' =$ ordinate of $A\ .\ T\ .\ D$.
$h_m =$ depth of the stiffening structure in the panel point m.

With regard to the angles, it is generally accepted and assumed and shall thus also be assumed here, that:

$$tng\ \alpha'_m = \frac{y^1{}_{m-1} - y^o{}_m}{\Delta x_m}\ ;\ tng\ \alpha''_m = \frac{y^1{}_m - y^o{}_{m-1}}{\Delta x_m}$$

$$tng\ \beta_m = \frac{y^1{}_m - y^1{}_{m-1}}{\Delta x_m}\ ;\ tng\ \gamma_m = \frac{y^o{}_m - y^o{}_{m-1}}{\Delta x_m}$$

$$tng\ \mu_m = \frac{y''{}_m - y''{}_{m-1}}{\Delta x_m}$$

This assumption fixes the angles as functions of $y^o\ y'\ y''$ in the panel points, leaving the form of the members between the panel points completely arbitrary. The member can have any form,

such as best adapted to resist the forces brought to bear upon it, provided the above rule is kept in the panel points.

Fig. 3.

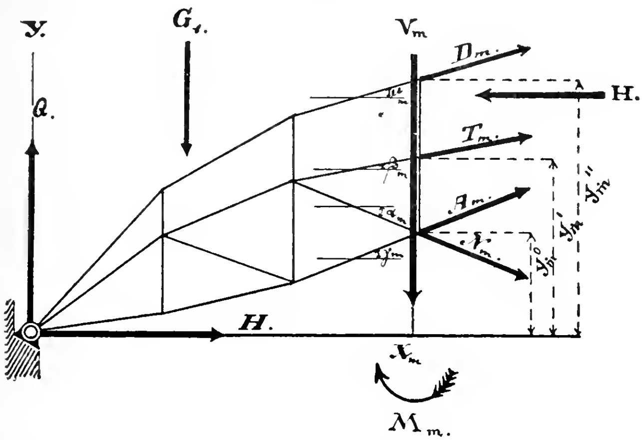

Fig. 3 represents a section in the *m*th panel infinitely near to *m*th panel point and the forces acting in it. *Fig.* 3 can be used as well for a slack bow as for a stiffened bow, in the latter case D being zero.

From *Fig.* 3 we can develop now directly the $\Sigma\,(x)$ $\Sigma\,(H)$ $\Sigma\,(x\,y)$. We have:

FOR A SLACK BOW

$$D_m \cos \mu_m + T_m \cos \beta_m + A_m \cos \gamma_m + N_m \cos \alpha_m - H = o \quad (1)$$

$$D_m \sin \mu_m + T_m \sin \beta_m + A_m \sin \gamma_m - N_m \sin \alpha_m - V_m = o \quad (2)$$

$$(D_m \cos \mu_m - H)\, y_m'' + T_m \cos \beta_m\, y_m' + (A_m \cos \gamma_m + $$
$$+ N_m \cos \alpha_m)\, y_m^o - M_m = o \quad (3)$$

FOR A STIFFENED BOW.

$$T_m \cos \beta_m + A_m \cos \gamma_m + N_m \cos \alpha_m - H = o \quad (1^a)$$

$$T_m \sin \beta_m + A_m \sin \gamma_m - N_m \sin \alpha_m - V_m = o \quad (2^a)$$

$$(T_m \cos \beta_m - H)\, y'_m + (A_m \cos \gamma_m + N_m \cos \alpha_m)\, y^o_m - M_m = o \quad (3^a)$$

to which must be added according to the premises:

$$D_m = \frac{H}{\cos \mu_m}$$

or

$$D_m \sin \mu_m = H \operatorname{tng} \mu_m$$

These equations give A, T, N, D.

Still, in accordance with the equilibrium of the forces in the whole structure, the forces must also be in equilibrium in each panel point. Hence in cutting out the panel points, and in applying the general conditions of equilibrium to the forces acting in each, we will be able to define in each panel point, *one more* unknown force, A, T, N, D being known, and beside this, it will be possible to bring the above general equations in a more convenient form. In cutting out the panel point of the bow strut we find (see *Fig. 5* or *Fig. 6*)

$$E_m = D_{m+1} \sin \mu_{m+1} - D_m \sin \mu_m$$

or

$$E_m = H (tng\ \mu_{m+1} - tng\ \mu_m) \qquad \text{(VIII)}$$

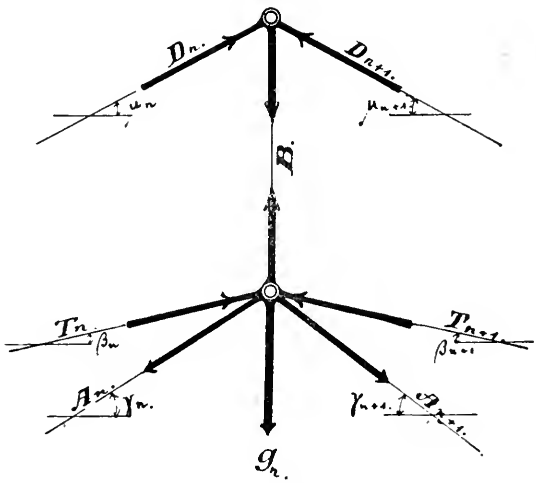

Fig. 4.

In cutting out the top joint of a slack bow, or the hanging abutment, we have:

$$B = D_n \sin \mu_n + D_{n+1} \sin \mu_{n+1}$$

or

$$B = H (tng\ \mu_n + tng\ \mu_{n+1}) \qquad \text{(IX)}$$

or from the bottom:

$$B = (T_n \sin \beta_n + T_{n+1} \sin \beta_{n+1}) - (A_n \sin \gamma_n + A_{n+1} \sin \gamma_{n+1}) + g_n$$

wherein g represents the loads taken up on bottom of B.

In place of A or T, strains of ties may take place, without altering the above results.

In cutting out the mth panel point of the lower and the $(m-1)^{\text{th}}$ panel point of the upper chord (see *Fig. 5*) we find:

$$\left.\begin{aligned} N'_m \cos \alpha'_m &= A_{m+1} \cos \gamma_{m+1} - A_m \cos \gamma_m \\ N'_m \cos \alpha'_m &= T_m \cos \beta_m - T_{m-1} \cos \beta_{m-1} \end{aligned}\right\} \qquad (\text{V}^a)$$

and (see *Fig. 6*)

$$\left.\begin{aligned} N''_m \cos \alpha''_m &= A_m \cos \gamma_m - A_{m-1} \cos \gamma_{m-1} \\ N''_m \cos \alpha''_m &= T_m \cos \beta_m - T_{m+1} \cos \beta_{m+1} \end{aligned}\right\} \qquad (\text{V}^b)$$

Whether we take the panel point from a structure with slack or with stiffened bow does not matter, as only the horizontal components of the forces come in question.

Introducing these new values in the general equations 1, 2, 3, and minding that:

$$D_m \cos \mu_m \, y''_m = H \, y''_m$$

$$D_m \sin \mu_m = H \, tng \, \mu_m$$

we have

FOR A SLACK BOW:

$$T_m \cos \beta_m + A_{m+1} \cos \gamma_{m+1} = o \qquad (4)$$

$$T_m \sin \beta_m - A_m \sin \gamma_m - N_m \sin \alpha_m = S_m \qquad (5)$$

$$T_m \cos \beta_m \, y'_m - A_{m+1} \cos \gamma_{m+1} \, y^o_m = M_m \qquad (6)$$

FOR A STIFFENED BOW

if we write:

$$T_m = \tau_m \pm H$$

as the upper chord is supposed to take up the whole thrust:

$$\tau_m \cos \beta_m + A_{m+1} \cos \gamma_{m+1} = o \qquad (4^a)$$

$$\tau_m \sin \beta_m - A_m \sin \gamma_m - N_m \sin \alpha_m = S_m \qquad (5^a)$$

$$\tau_m \cos \beta_m \, y'_m + A_{m+1} \cos \gamma_{m+1} \, y^o_m = M \qquad (6^a)$$

Multiplying eq. (4^a) or (4) alternatively with y^o_m and y''_m, and deducting eq. (6) or (6^a) we find then, if we remember that the moments can be as well positive as negative, and that $y'_m - y^o_m = h_m$ is the depth of the stiffening structure in the point under consideration.

FOR A SLACK BOW.

$$A_{m+1} \cos \gamma_{m+1} = \pm \left(\frac{M}{h}\right)_m$$

$$T_m \cos \beta_m = \pm \left(\frac{M}{h}\right)_m$$

FOR A STIFFENED BOW.

$$A_{m+1} \cos \gamma_{m+1} = \pm \left(\frac{M}{h}\right)_m$$

$$\tau_m \cos \beta_m = (T_m \pm H) \cos \beta_m = \mp \left(\frac{M}{h}\right)_m$$

or,

$$T_m = \mp \left(\frac{M}{h}\right)_m \pm H$$

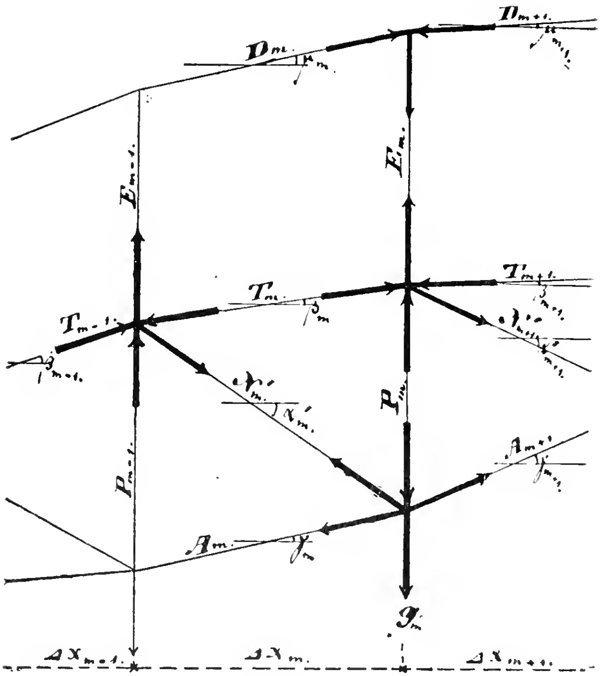

FIG. 5.

From these expressions follows, as the lower chord as well as the upper one, can take up the thrust, the general expression of the *horizontal component of the chord strains*:

$$U_m = \pm \left(\frac{M}{h}\right)_m \pm H$$

In this expression H is zero, if the thrust is *not* taken up by the chord in question. But not only H may become zero, M also

can be zero in certain panels, and then the above equation takes the form :

$$U_{\rm m} = \pm H$$

It is thus necessary to be very careful in calculating the chord strains, as the moments become generally zero in one panel point of the chord only, creating in this way *one* panel in the chord, in which the chord strains are completely different of the strains in

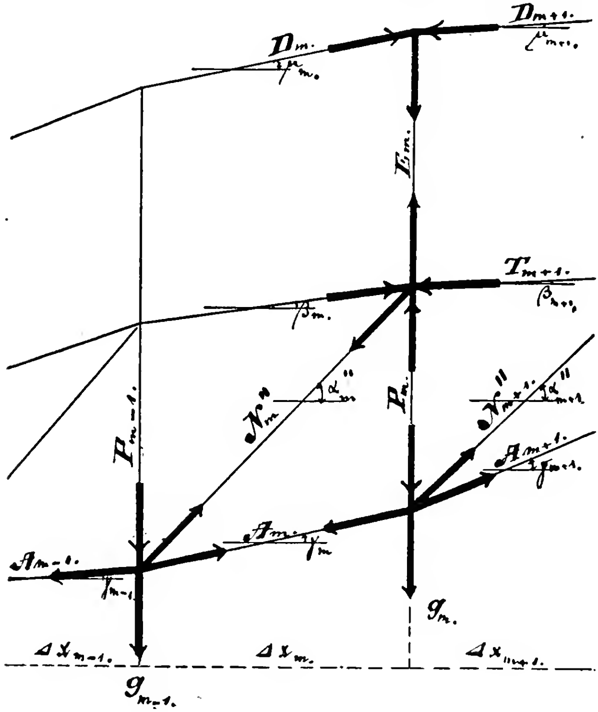

FIG. 6.

all the other panels. The above equation gives the following combinations :

$$U_{\rm m} = \pm \left(\frac{M}{h}\right)_{\rm m} + H$$

$$U_{\rm m} = \pm \left(\frac{M}{h}\right)_{\rm m} - H$$

Hence we can write quite generally *without* regard to the sign,

$$U_{\rm m} = \left(\frac{M}{h}\right)_{\rm m} \pm H \qquad \text{(IV)}$$

We have assumed that the thrust strains were taken up, fully and completely by *one* chord, but the above equation of the chord strains shows that the results of the investigations and the investigations themselves would not change in the slightest way, if the thrust were distributed over both chords. The only difference would be, that in place of the whole thrust a part of it $= K\,H$ would go in the chord strain of one chord, and the balance, or $(1 - K)\,H$ in the other chord. The above equation:

$$U_m = \left(\frac{M}{h}\right)_m \pm H$$

is thus quite generally the expression of the chord strains, however the thrust may be distributed over the chords, if H represents that part of the thrust taken up by the chord in question. In using now eq. (IV) in eq. (V^a) and (V^b) we find:

$$N'_m \cos \alpha'_m = \left[\left(\frac{M}{h}\right)_m \pm H\right] - \left[\left(\frac{M}{h}\right)_{m-1} \pm H\right] = \left(\frac{M}{h}\right)_m -$$

$$- \left(\frac{M}{h}\right)_{m-1} = U_m - U_{m-1} = W'_m$$

$$N''_m \cos \alpha''_m = \left[\left(\frac{M}{h}\right)_{m-1} \pm H\right] - \left[\left(\frac{M}{h}\right)_m \pm H\right] =$$

$$= \left(\frac{M}{h}\right)_{m-1} - \left(\frac{M}{h}\right)_m = U_{m-1} - U_m = W''_m$$

or quite generally

$$W_m = N_m \cos \alpha_m = U_m - U_{m-1} = \left(\frac{M}{h}\right)_m - \left(\frac{M}{h}\right)_{m-1} \qquad (V)$$

This equation is of the greatest importance for the knowledge of the way, in which the forces are acting in the structure.

In substituting eq. (IV) and eq. (V) in eq. (4), (5), (6), or eq. (4^a), (5^a), (6^a), we can for the rest bring N_m also in the form:

$$N_m = \frac{S_m - \left(\frac{M}{h}\right)_m (tng\,\beta_m + tng\,\gamma_m)}{sin\,\alpha_m \pm cos\,\alpha_m\,tng\,\beta_m}$$

In cutting out the panel point of the lower or upper chord and decomposing the forces in the direction of the Y axis, we shall

find the strains in the posts, but there are *three* distinct cases to investigate:

(1) *One* tie is acting.
(2) *Two* ties are acting.
(3) *No* tie is acting.

ONE TIE IS ACTING.

Upper Chord.

$$N'_{m+1} \sin \alpha'_{m+1} + T_{m+1} \sin \beta_{m+1} - T_m \sin \beta_m + E_m = P_m$$

$$N''_m \sin \alpha''_m + T_{m+1} \sin \beta_{m+1} - T_m \sin \beta_m + E_m = P_m$$

Lower Chord.

$$N'_m \sin \alpha'_m + A_{m+1} \sin \gamma_{m+1} - A_m \sin \gamma_m - g_m = P_m$$

$$N''_{m+1} \sin \alpha''_{m+1} + A_{m+1} \sin \gamma_{m+1} - A_m \sin \gamma_m - g_m = P_m$$

or in introducing

$$N_m \cos \alpha_m = W_m$$

and for the chords strains the corresponding U, we have:

Upper Chord.

$$W'_{m+1} \operatorname{tng} \alpha'_{m+1} + U_{m+1} \operatorname{tng} \beta_{m+1} - U_m \operatorname{tng} \beta_m - E_m = P_m$$

$$W''_m \operatorname{tng} \alpha''_m + U_m \operatorname{tng} \beta_{m+1} - U_{m-1} \operatorname{tng} \beta_m - E_m = P_m$$

Lower Chord.

$$W'_m \operatorname{tng} \alpha'_m + U_m \operatorname{tng} \gamma_{m+1} - U_{m-1} \operatorname{tng} \gamma_m - g_m = P_m$$

$$W''_{m+1} \operatorname{tng} \alpha''_{m+1} + U_{m+1} \operatorname{tng} \gamma_{m+1} - U_m \operatorname{tng} \gamma_m - g_m = P_m$$

From these expressions we deduct the general equation of P, in introducing for β or γ the angle ρ expressing the inclination of the chord member against the x axis, and in remembering that E or g can as well act in the upper as lower chord.

$$P_m = W_m \operatorname{tng} \alpha_m + U_m \operatorname{tng} \rho_m - U_{m-1} \operatorname{tng} \rho_{m-1} \pm E_m \mp g_m$$

TWO TIES OR NO TIE ACTING.

Both cases are identical. When two ties are acting on one end of the post the other end must necessarily be free of the action of any tie, as N'_m and N''_m can never act together at once in one and the same panel, being in tension.

Two ties or no ties correspond thus to the case of $W = o$, and we have:

$$P_m = U_m \operatorname{tng} \rho_m - U_{m-1} \operatorname{tng} \rho_{m-1} \pm E_m \mp g_m$$

These equations give the internal strains of the structure as functions of M and H, and it remains now to show how the maximal and minimal values of the forces in the members of the bow are found. But before I enter into these investigations, I will deduct from the above equations some quite

GENERAL RULES.

We have:

$$U_m = \left(\frac{M}{h}\right)_m \pm H \qquad \textbf{(IV)}$$

$$W_m = \left(\frac{M}{h}\right)_m - \left(\frac{M}{h}\right)_{m-1} = U_m - U_{m-1} = \Delta U_m \qquad \textbf{(V)}$$

$$P_m = W_m \, tng \, \alpha_m + U_m \, tng \, \rho_m - U_m \, tng \, \rho_{m-1} \pm E_m \mp g_m \qquad \textbf{(VI)}$$

$$D_m = \frac{H}{cos \, \gamma \, \mu_m} \qquad \textbf{(VII)}$$

$$E_m = H (tng \, \mu_{m+1} - tng \, \mu_m) \qquad \textbf{(VIII)}$$

$$B = H (tng \, \mu_{n+1} + tng \, \mu_n) \qquad \textbf{(IX)}$$

and from the first part:

$$M \;.\; S \;.\; H.$$

If we consider these equations, we see that quite generally U, W and P have the same relations to each other as M . S . and W, to wit:

M	U
$S = \dfrac{M_{m-1} - M_m}{\Delta x_m}$	$W = \Delta U_m = U_m - U_{m-1}$
$W = S + K M$	$P = W + K' U$

if we represent W, which is

$$\left(\frac{M}{h}\right)_m - \left(\frac{M}{h}\right)_{m-1}$$

by $K M$.

In the first serie S is the increment *of M per unit of length*, in the second serie W is the *total increment of U*. W is thus a very important strain, and I shall make use of the above property to decide the maxima and minima of U.

Still another quite general property of the bow structures can be deducted from the above equations with the aid of the first part.

As we know from the first part, those structures whose lines of thrust coincide with one of the sides of the deciding triangle, or structures with a *straight line*, as line of thrust, have their maximum and minimum of the moments with full-loaded or empty girder, and it will be, if the line of thrust coincides with $D\ C$ or the upper side of the deciding triangle $a = o$, if $A\ C$ or the lower side of the deciding triangle is the line of thrust $c = o$, that is all; *all the forces, with exception of H, are then independent of the loadings of one-half of the structure.*

If we consider now the expression of E, we see that in case of a *straight line of thrust, no thrust at all* is transmitted to the members of the structure, μ_m being μ_{m+1}, and $E = o$. *In case of a straight line of thrust, the bow structure is thus reduced to two inclined ordinary beams—struts—whose longitudinal members have to bear an additional thrust.*

(*To be continued.*)

OBITUARY.

Barnabas H. Bartol.

Barnabas H. Bartol, who died in this city upon the 10th of February, 1888, was one of Philadelphia's ablest engineers and one of the warmest friends of the Franklin Institute.

He was born at Freeport, Cumberland County, Me., October 31, 1816, the son of Barnabas Bartol, and Rebecca, his wife, who removed, eighteen months later, to Portland, Me., where he became largely interested in shipping interests. In 1830, he removed with his family to New York.

The subject of this memoir was educated at a private school, taught by a Mr. Jackson.

On the 4th of March, 1833, being then sixteen years four months old, he was entered as an apprentice, until of full age, with Messrs. Kemble, who conducted a branch of the West Point Foundry in New York. It is said that his father wished him to enter the office and drawing room, but it was his own plan to

become a regular apprentice for the purpose of acquiring a thorough knowledge of the practice and details of the profession.

He thus exhibited at the outset a leading characteristic, which was illustrated during all of his subsequent career. In 1835, he was sent as an assistant to erect a coal-winding engine near Richmond, Va., and also in the same year to assist in the erection of water works machinery in the city of New Orleans. In 1837, while still an apprentice, he was sent in charge to erect the first beam engine on Seneca Lake on the steamboat *Richard Stevens*, and in the summer of the same year to the vicinity of Richmond, Va., to erect a winding engine in the coal mines. In both of these last-mentioned works, he was assisted by a fellow-apprentice, W. W. Wood, subsequently of the United States Navy and Chief of Bureau of Steam Engineering.

Becoming of age, October 31, 1837, and free from his apprenticeship, he went to East Boston, with a view of engaging in business, but was prevented by the disastrous effects of the reduction of the import duties under the operation of the "Compromise Act" of 1833, which deranged business generally. He returned to the West Point Foundry, and in October, 1838, was sent to the Island of Cuba to erect sugar machinery.

On his return in June, 1839, he found the New York branch of the West Point Foundry consolidated with the parent establishment at Cold Spring. About the same time, the engineer and Superintendent, Mr. Charles W. Copeland, retired, being engaged by the Navy Department to design the machinery of the steam frigates *Mississippi* and *Missouri*. Messrs. Kemble offered the vacant position to Mr. Bartol, who was then not quite twenty-three years old. He accepted, and remained in their employ until September, 1847, when he resigned and removed to Philadelphia, to become the engineer and Superintendent of the Southwark Foundry, then belonging to Messrs. Merrick & Towne, and subsequently to Messrs. Merrick & Son. In this employ and capacity he remained until January 1, 1867.

During this period many important works were executed by the firm, some of which were designed by him personally; among them may be mentioned, as most important, the machinery of the United States ship *Wabash*, and the hull and armor plating of the United States steam iron-clad *New Ironsides*, besides many other steamers.

His design submitted upon the invitation of the Chesapeake & Delaware Canal Company, for competitive plans for supplying their locks with water was awarded the premium and the work was executed from his drawings, and under his supervision.

The work of the Southwark Foundry during his incumbency as Superintendent was large, varied and important. The knowledge of machinery for gas making possessed by the founder, Mr. S. V. Merrick, brought it many orders and contracts for building and extending works in the country. The contracts by which the firm became the exclusive agents of Mr. James Nasmyth, the inventor of the steam hammer, and of M. Norbert Rillieux, inventor of the famous "triple effect" system of boiling cane juice into sugar, brought to the establishment a large business from both directions, and to MR. BARTOL a large fund of varied experience, which was of great advantage to him afterwards.

We have traced in detail the principal events in MR. BARTOL'S career, whilst he was in a subordinate capacity, because of the striking lesson it presents of the success which attends the strict attention to duties and studies.

The spectacle of a young man under twenty-three years of age, placed at the head of an establishment like the West Point Foundry, where he had lately been an apprentice, is a very remarkable one, and a proof of his acknowledged ability. His successful management, against the jealousies which his promotion would naturally excite, is the best proof of the moral qualities which he afterwards exhibited.

On leaving the Southwark Foundry, MR. BARTOL visited Europe for six months with a part of his family, and inspected the French Exposition of 1867. On his return, he devoted himself to the management of the Grocers' Sugar House, an establishment built by him in 1859, being the first sugar house in Philadelphia to use centrifugal draining machines, and also to the management of the Washington (D. C.) Gas Light Company, of which he was elected President in 1864, and continued in that office until 1883, to the great advantage of the company. In 1872, he was elected a Director of the American Steamship Company, and served eight years as Chairman of the Building Committee.

During the war the President offered to MR. BARTOL the posi-

tion of Engineer in Chief of the United States Navy, but, after consultation, it was decided that he would be of more use to the Government by remaining in Philadelphia and completing the *New Ironsides*, and other vessels upon which he was engaged.

MR. BARTOL'S connection with the FRANKLIN INSTITUTE began soon after his arrival in this city. He served on the Board of Managers for three years, 1863, 1864, 1865. In 1880 he presented to the INSTITUTE $1,000 invested in City 6's. With his consent the interest was devoted to providing prizes of free scholarship to be given to those pupils of the Drawing School who were most deserving. He always exhibited the greatest interest in the prosperity of the INSTITUTE, and was always ready to assist in promoting its welfare.

In 1851, MR. BARTOL published a treatise on "Marine Boilers," which was fully abreast the practice of the day, and contains full details of the boilers of the principal vessels afloat.

MR. BARTOL was married in 1842 to Miss Emma J. Welchman, originally of England, by whom he had four children, two sons and two daughters, who all survive him.

One who knew him intimately, writes:

"The perfect harmony which always existed between MR. BARTOL and myself enabled us to work together without the slightest friction, and no disagreement ever arose between us during our long association of twenty years.

"MR. BARTOL'S characteristics were: (1) Method and attention to details in managing the work both in its execution, its shipment and its erection. (2) Uncompromising discipline and control over subordinates, yet combined with a sufficiently affable manner; every one had confidence that while he would be kept up to the line of duty, he would be treated considerately. (3) A direct practical judgment—no room given for sentiment or imagination—the question at issue being decided on its merits and generally with accuracy.

"This judgment derived much of its value from his thorough mastery of details acquired during his early training. He saw what would be required, how it could be done and how soon, and decided accordingly."

Mr. BARTOL possessed superior administrative abilities, coupled with untiring energy and perseverance, and a comprehensive

knowledge of his profession. These qualities, with eveness of temper and straightforward honesty, formed a combination rarely found, and fitted their possessor for the responsible positions filled by him, and brought success to the enterprises of a busy, well-spent life.

W. P. TATHAM, WM. SELLERS, WASHINGTON JONES.

BOOK NOTICES.

MANAGEMENT OF ACCUMULATORS AND PRIVATE ELECTRIC LIGHT INSTALLATIONS. A practical hand-book by Sir David Salomons. pp. 150. Third edition. London: Whittaker & Co. 1888.

When storage batteries first came into use it was claimed by many that they would revolutionize electric lighting; but it was soon found, after they had been in use for a short time, that numerous unforeseen and serious difficulties presented themselves, and that, therefore, the only way to find out their true value was to conduct long series of experiments with them in actual practical installation. This little volume, will, therefore, be very acceptable to those interested in the subject, as giving the experience of one who has for a number of years used accumulators for a private installation, and who is, therefore, competent to give an unbiased description of their behavior, their "idiosyncrasies" and the results of their continued use.

The matter contained in the book is, to a great extent, comprised of the results of the author's personal experience with accumulators of a particular type, in the private lighting installation at his residence. The book is chiefly for amateurs and persons who are not electricians, but it may also be read with profit by electricians who have not had much personal experience with the management and behavior of accumulators. With a few exceptions, the language is clear and concise and requires but little familiarity with the subject on the part of the reader. In a few cases, statements are made as facts, while they are really matters of opinion only, which may be misleading to the inexperienced. In a few other cases, his too positive assertions might better have been modified somewhat, while others will bear correction.

The author limits himself almost entirely to a particular company's cells, but his statements apply, in a great measure, also to accumulators in general which resemble this type, namely, those having plates consisting of lead grids having their meshes filled with the active material. In endeavoring to assist parties in selecting reliable apparatus, the author has given some parts of the book the appearance of advertisements of certain firms. A few statements are not quite correct; "force" and "energy," for instance, are not synonymous terms, and a "watt" is a measure of *power*, and not of "force." About half of the book is devoted to accumulators, and the other half to the remaining parts of an installation, the former being by far the more important part of the book.

In the first few chapters, the author describes the particular cells, namely, the E. P. S. cell, and gives much valuable information regarding the details which should be observed in setting up, charging and discharging the cells, giving the causes of failure and their remedies. Among other information which may not be generally known, he states that "sunlight falling upon the cells is a constant source of breakage." He gives as the proper rate of charging and discharging, 5·3 ampères and 6·1 ampères per square foot of positive plate respectively, and dwells on the great importance of not exceeding these figures.

From a few remarks he makes, we cannot but conclude that even in this model installation there is much room for improvement. For instance, he states that gas is given off at all periods of the charge (which, of course, represents loss of energy); that unless well ventilated it is almost impossible to enter the apartment during charging hours, on account of the gases; and that a charging current of one-tenth the normal does not appear to charge the cells (presumably on account of the leakage). For total efficiency on the long run, he states that more than sixty-five to seventy per cent. cannot be counted upon. A few tables which are given contain some useful figures regarding the storing capacity and weights of various cells. The chief faults of storage batteries of this type are the buckling of the peroxide plates and the falling out of the active material from the meshes in the grids. Unfortunately, nothing is said of the length of time the peroxide plates will last before their grids are peroxidized throughout, which determines their life, and which is a very important factor in determining the cost of running a plant, as these plates, he admits, are quite expensive.

The accessory apparatus of an installation the author describes in detail, calling attention to important points, and recommending apparatus of certain firms as a guide to installers of plants. He states that "Edison's meter is a thing of the past; * * * * it requires a shunt resistance and, therefore, is wasteful for large currents." We would remark here that all meters having, like Edison's, an approximately constant total resistance, are alike in consuming a larger amount of energy as the current increases.

He describes at some length one of the most important pieces of apparatus in such a plant, namely an automatic switch for preventing the accumulators from discharging through the dynamo. But unfortunately the diagram of this (page 115) is incomplete and not clear, and therefore almost worthless to one not able to supply what is omitted.

The latter part of the book contains a table of estimates of the various items and totals in the first cost and cost of running small private plants from twenty-five to 120 lamps, with and without accumulators. The figures and the deductions from them are of considerable interest and may be of great use to anyone making such estimates or comparisons.

The concluding chapter gives a brief account and history of the author's private installation at Broomhill, in which he gives the expense accounts and deduces the cost per sixteen candle-power lamp per hour, which he states was, in 1887, at the rate of three-eighths pence, or about three-fourths of a cent, even under very unfavorable circumstances.

Apart from the few points to which exception may be taken, the book may be highly recommended to persons interested in the subject, and who have not had a similar practical experience with accumulators, some parts being of interest and use even to the experienced electrician. It is an important and valuable addition to the scant amount of literature on this important subject. It is hoped that the author will supplement it in the near future with additional information, particularly with reference to the life of the cells. C. H.

THE ANOINTED SERAPH. "The last made first." By G. H. Pollock. Vol. I. John F. Sherry, printer and publisher, 623 D Street, N. W., Washington. 1888.

This little book is a fine sample of the sort of structure a morbid mind can raise when it has for material a supposed divine revelation. It is an utterly unintelligible jumble of meaningless mysticisms about nothing at all, as the following extract will illustrate:

"The earth which we inhabit, and of which we are a part, was made up, through involution, of all the various products and qualities of the disturbed stellar lights: Water came from Taurus, oxygen from the Great Bear, amativeness from Capricornus, copper from the Whale, steel from the Little Bear, gems from Scorpio, black hair from Aquarius, gold from the Crown, salt from Orion, mercury from Mercury, sulphur from Jupiter, alkaline substance from Venus, diamonds from Andromeda, verdigris from the Sun-spots, iron from Hercules, silver from the Pleiades, soapstone from Hydra, loadstone from the Pole Star. The life of the world was the nature and personality of the Digressor from the seventh sun, who, through the process of involution, became inverted; passing from the Divine to the natural state." T.

PHOTOGRAPHY APPLIED TO SURVEYING. By Lieut. Henry A. Reed, U. S. A. New York: Jno. Wiley & Sons.

Among the most recent contributions to engineering literature is Lieut. Henry A. Reed's interesting work on "Photography Applied to Surveying." As the author states, the principles involved in the use of photographs for map construction are old, though, in this country, at least, their practical application is very rare.

The general principles, as set down by Lieut. Reed, are exactly the same as for ordinary surveying. A point is determined from the station, horizontally, by the intersection of two "spots" or "views" from given points, or by its azimuth and distance, and, vertically, by measuring the angle of elevation or depression.

The field work with the camera consists simply in taking views, with compass bearings, from stations either previously determined or not, so as to include as much of the tract to be surveyed as possible.

These data suffice for making an exceedingly complete and surprisingly accurate topographical map. The author states that, with care, the maximum error in determining a point 2,700 yards off would not be over twenty inches

in distance or thirty seconds in angular height. Reduced to a scale of 1:5000 (one of the scales used by the Corps des Ponts et Chaussées for exact details), such inaccuracies would be inappreciable.

The latter part of Lieut. Reed's book is taken up in describing improved French photographic instruments for surveying, as well as telescopic and balloon photography, showing that this method of photographic surveying has acquired a foothold abroad.

When the great saving of time in both field work and plot are considered, it becomes important for engineers to investigate a method that for ordinary purposes gives such remarkably good results. For this purpose, Lieut. Reed's work is admirably adapted.

C. H. H.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, May 16, 1888.*]

HALL OF THE INSTITUTE, May 16, 1888.

Mr. JOS. M. WILSON, President, in the Chair.

Present, 348 members and fifty-one visitors.

Additions to membership since last report, fifteen.

Mr. EMILE BERLINER, of Washington, read a paper on his lately-invented apparatus for recording and reproducing musical sounds and speech, called the "Gramophone." Mr. BERLINER'S paper contained a historical sketch of the progress of invention in this field and a detailed description of his own method and apparatus. The speaker illustrated his paper with the aid of the lantern, and by the exhibition of the apparatus. He demonstrated its capabilities by recording on one of his prepared zinc plates several songs and speeches, etching the plate, and reproducing the songs and words then and there. Several etched record plates, prepared previous to the meeting, were likewise presented, and the reproducing apparatus faithfully emitted the songs and spoken words recorded upon them. The reproduction was loud enough to be distinctly audible all over the lecture room. The music could be easily recognized; speech, though not so clearly rendered, was, for the most part, intelligible.

Mr. BERLINER explained that the apparatus which he exhibited was the first that he had constructed, and that it had only been finished a few days before. He felt satisfied that after some experience with it he would be able to make such betterments in its mechanical details as would substantially improve its performance.

On Prof. HOUSTON'S motion, a unanimous vote of thanks was tendered to Mr. BERLINER for his most interesting paper and demonstration.

The Secretary called attention to a remarkable suite of specimens of various forms of iron and steel that had been produced by rolling with the Simonds rolling machine, and added that a paper on the subject would be read at the stated meeting in June.

Adjourned. WM. H. WAHL, *Secretary*.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN FOR JANUARY, 1888.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 31, 1888.

The new year's report shows a very creditable increase of stations over the last, but it will not be complete until every county in the State is represented. Observers are wanted in the following counties: Adams, Beaver, Cambria, Carbon, Greene, Jefferson, Juniata, Lehigh, Mifflin, Potter, Snyder, Union and Wyoming. The value of reliable records of the climate of every portion of the State is apparent, and the opportunity to secure the standard instruments, which the Committee holds for the counties above named, should not be neglected by them.

The Committee has received numerous applications for instruments for additional observation stations in the counties already supplied, but is unable to grant them without crippling its ability to supply each county in the State as provided by law.

Those having instruments of their own, who desire to join the Service, will be gladly welcomed, suitable forms and instructions furnished them, and their reports published. The State Service was organized for the benefit of the people of Pennsylvania. The larger the force of observers and displaymen, the greater will be the facilities to accomplish its purposes. Observers are particularly requested to provide substitutes to take their observations during times when they cannot attend to them, so that their records may be complete and continuous.

The editors of papers and the various organized associations throughout the State are earnestly requested to assist the Service in obtaining observers and displaymen.

The taking of observations is a pleasant pastime for ladies, and those already in the service have shown a remarkable aptitude for the work.

The Chief Signal Officer has made arrangements to telegraph the indications and cold-wave warnings to those who will display the Weather Signal Flags. Where the displayman can have access to the Bulletins displayed at Railway Stations, no special telegraphic advices will be required for the indications. The necessary arrangements will be made for this information by the State Service, on application addressed to Sergeant T. F. Townsend, State Weather Service, Philadelphia. The State Service will furnish flags to a few selected stations.

The Committee desires to acknowledge its obligations to the following railroad companies for facilities offered:

The Pennsylvania Railroad Company.

The Philadelphia and Reading Railroad Company.

The Lehigh Valley Railroad Company.

The Committee on Meteorology of the FRANKLIN INSTITUTE,
W. P. TATHAM, *Chairman.*

REVIEW FOR JANUARY, 1888.

TEMPERATURE.

The characteristics of January, 1888, were the distinctive thermal periods of abnormal warmth and cold, dividing the month into two equal parts.

The mean daily temperatures, as compared with the mean daily temperatures deduced from the records of fifteen years, show a daily excess of about 5° during the first half of the month, and a daily deficiency of about 10° during the last half. At the end of the month there was a total deficiency of temperature amounting to 49° at Pittsburgh, 106° at Philadelphia, and 179° at Erie.

The mean temperature for the month was 22·1, which is probably 5° below the normal.

The highest temperatures occurred on the 1st and 7th, and ranged from 61° at Pittsburgh, to 40°·5 at Carlisle.

The lowest temperatures were on the 22d and 23d, and the following were noted: Dyberry,—19°; Wellsboro,—16°; Columbus,—15°; Eagles Mere,—14°; Greenville,—14°, and Clarion,—13°·5.

The mean maxima temperatures for the month was 30°·2, and the mean minima 16°·3. These show a daily mean of 23°·2, which is 1°·1 above that obtained from the tri-daily observations at 7 A. M., 2 P. M., and 9 P. M.

ATMOSPHERIC PRESSURE.

The mean barometric pressure was nearly .08 above the normal.

The lowest pressure (29·49 at Erie) occurred on the 1st. This depression was attended with the highest temperatures and the heaviest rainfall of the month.

The second low pressure was during the snowstorm of the 25th and 26th, and was followed by high Northwest winds, which drifted the snow and caused serious blockades.

A high pressure on the 11th and 12th was attended by low temperatures and generally fair weather. The unusual and extreme high barometer, 30·86 at Erie, 30·83 at Philadelphia, and 30·820 at Pittsburgh, occurred on the 16th, and heralded the cold period which prevailed from that date to the end of the month.

The third high pressure had for its escort the extreme cold of the 22d and 23d.

PRECIPITATION.

The precipitation for the month amounted to an average of 4·19 inches, which is nearly one inch in excess of the monthly average. Of this amount (4·19 inches) 1·40 inches was melted snow and hail. The rain and snowfall was very unevenly distributed, and ranged from 6·75 inches at Indiana, 6 17 inches at Pittsburgh, 6·04 inches at Huntingdon, to 2·12 inches at Chambersburg. Excepting the 14th and 22d rain or snow fell in measurable quantities on every day on some part of the State. The greatest amount, and the most rainy days, occurred in Western Pennsylvania. Most of the storms were mixtures of rain, snow and sleet.

SNOWFALL.

The total depth of snowfall (unmelted) during the month, averaged 14 inches. Eagles Mere reports 41 inches; Meadville, 31 inches; Blooming Grove, 19 inches; Dyberry, 18 inches; Wellsboro, 17 inches, and Bernice, 16 inches. The snowfall of the 25th ranged from 6 to 12 inches, where the blockades occurred. The snow was fine and dry, and was followed by high Northwest winds, which drifted it until many of the country roads were "fence full," and the railroad cuts rendered impassable. Several trains were delayed for hours, some had to be dug out, and several teamsters were obliged to abandon their wagons on the road. The obstruction caused by drifts is said to have been the worst for years, in many parts of the State, and travel for a time was almost suspended.

WIND AND WEATHER.

Prevailing direction, Northwest.

Average number of clear days, 5; fair days, 11; cloudy days, 15; rainy days, 13.

MISCELLANEOUS PHENOMENA.

Auroras.—Eagles Mere, 8th; Clarion, 11th; Indiana, 13th; Greenville, 13th; Bernice, 13th; Charlesville, 13.

Solar Halos.—Charlesville, 3d; Eagles Mere, 12th, 16th, 20th, 22d, 23d, 24th, 25th, 28th; Wellsboro, 12th, 15th; Quakertown, 23d; West Chester, 25th; Dyberry, 25th.

Parhelias.—Eagles Mere, 20th; Dyberry, 27th, 28th.

Lunar Halos.—Philadelphia, 2d, 24th; Pottstown, 18th; West Chester, 19th, 24th, 25th; Indiana, 19th, 20th; Catawissa, 19th, 24th, 25th; Wellsboro, 19th, 26th; Bernice, 19th; Greensburg, 19th; Eagles Mere, 19th, 27th; Somerset, 20th, 24th; Carlisle, 22d, 24th; Dyberry, 23d, 24th, 28th; Scranton, 23d; Quakertown, 24th; Clarion, 24th; Lebanon, 24th; Lancaster, 24th; Greenville, 24th; Shamokin, 24th.

Lunar Coronæ.—Huntingdon, 20th; Lebanon, 20th; Greensburg, 25th; Greenville, 27th; Indiana, 27th.

REMARKS.

The ice harvest was a prolific one and good crops have been secured.

Winter wheat has been well protected and is in good condition.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.

Displayman.	*Station.*
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.

(Jour

ER SERVICE FOR JANUARY, 1888.

Cou	Dew Point.	Precipitation. Total Inches.	Total Depth of Snow (inches).	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers.
Allegheny	20·7	6·17	9·4	22	2	10	19	W	Oscar D Stewart, Sgt. Sig. Corps.
Armstrong	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Tyson Heilman.
Bedford,	16 8	4·06	9·5	11	5	11	15	NW	Rev. A. Thos. G. Apple.
Berks, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. George A. Ruddle.
Berks, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. J. H. Rohrbach.
Blair, . .	15·6	5·69	16·5	11	5	15	11	W	Prof. J. A. Stewart.
Bradford,	14·6	2·63	13·0	7	7	8	16	NW	Charles Beecher.
Bucks, . .	18·3	4·45	15·5	14	4	17	10	NW	J. L. Heacock.
Butler,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. E. Forsythe.
Cameron,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	A. H. Boynton.
Centre, . .	18·0	3·46	17·3	13	3	13	15	W	Prof. Wm. Frear.
Centre, . .	. . .	3·52	14·0	14	3	10	18	SW	L. Ray Morgan.
Chester, .	. . .	5·89	. . .	17	11	10	10	NW	Jessie C. Green, D.D.S.
Chester, .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	W. T. Gordon.
Clarion, .	17 3	4·88	12·5	13	3	9	19	W	J. H. Apple, A.B.
Clearfield,	. . .	5·77	20·0	15	2	9	19	W	Nathan Moore.
Clinton, .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. Wallace P. Dick.
Columbia,	. . .	3·58	10·8	14	. . .	. . .	. . .	. . .	Wm. G. Yetter.
Crawford,	14·6	4·49	30·5	14	3	9	19	W	Prof. J. H. Montgomery.
Cumberland	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Charles F. Himes, Ph.D.
Cumberland	. . .	3·30	10·5	13	7	11	13	—	J. E. Pague.
Dauphin,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Zenos J. Gray, M.D.
Delaware,	19·8	4·57	—	12	9	10	12	N	Prof Susan J. Cunningham.
Elk, . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Joe Messinger.
Erie, . . .	16·0	2·79	13·0	24	1	10	20	NW	Peter Wood, Sgt Sig. Corps.
Fayette, .	22·5	5·69	5·5	9	5	12	14	SW	Wm. Hunt.
Forest, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Robert L. Haslet.
Franklin, .	16·0	2·12	13·0	8	8	11	12	—	Miss Mary A. Ricker.
Fulton, . .	18·4	4·32	10·5	12	8	10	13	W	Thomas F. Sloan.
Huntingdon	19·1	6·04	11·7	12	13	8	10	W	Prof. W. J. Swigart.
Indiana, . .	21·0	6·75	13·4	17	3	9	19	SW	Prof. Albert E Maltby.
Lackawanna	15·2	4·36	14·8	13	9	10	12	W	T. F. Heebner, M.D.
Lancaster,	16·8	4·79	15 2	13	5	13	13	W	A. M. Schmidt, A.B.
Lawrence,	20·1	2·77	4·7	13	4	11	16	NW	Wm. T. Butz.
Lebanon, .	12·7	1·64	11·9	8	6	8	7	NW	George W. Hayes, C.E., Ph G.
Luzerne, . .	. . .	3·79	. . .	9	. . .	. . .	. . .	. . .	H. D. Miller, M.D.
Lycoming, .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	E. H. Baker.
McKean, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Armstrong & Brownell.
Mercer,	15·2	3·50	11·4	21	1	9	21	NW	Prof S. H. Miller.
Monroe, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	N. C. Miller, M.D
Montgomery,	16·8	4·31	—	10	9	11	11	NW	Charles Moore, D.D.S.
Northampton,	15·8	5·09	. . .	8	. . .	. . .	. . .	W	Lerch & Rice.
Northumberla	17·2	2·57	8·2	11	5	14	12	NW	G. R. Hanley.
Perry,	. . .	2·47	12 8	9	11	9	11	W	Frank Mortimer.
Philadelphia,	19·3	4·30	6·5	15	6	14	11	NW	Luther M. Dey, Sgt. Sig. Corps.
Pike, ...	. . .	2·90	19·0	15	. . .	. . .	. . .	W	John Grathwohl.
Schuylkill, .	. . .	3·50	11·8	9	9	10	12	NW	E. C Wagner.
Somerset, .	19·0	6·40	25·8	16	5	8	18	NW	W. M. Schrock.
Sullivan, . .	5·2	6·16	41·3	12	3	11	17	NW	E. S. Chase.
Sullivan, . .	11·6	2·95	16·2	14	3	11	15	N	C R. Claghorn.
Susquehanna,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	A. H. Berlin.
Tioga, ...	. . .	3·70	16·9	11	2	6	23	N	H. D. Deming.
Washington,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Jacob Gayman.
Washington,	. . .	5·56	—	11	4	5	15	NW	Harrison Otis.
Warren, . . .	. . .	3·32	—	19	2	4	25	SW	Wm. Loveland.
Wayne, . . .	. . .	4·38	18·2	16	6	7	18	NW	Theodore Day.
Westmoreland,	21·8	5·06	10·6	14	2	11	18	W	H. S. Brunot.
York,	17·5	2·70	7·3	7	9	10	12	NW	Mrs. L. H. Grenewald.

* From Fe

† From Fe

T. F. TOWNSEND,

Sergeant Signal Corps, Assista

(Jour. Frank. Inst., Vol. CXXV. March, 1888.)

Monthly Summary of Reports of Voluntary Observers of the Pennsylvania State Weather Service for January, 1888.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Depth of Snow (inches).	Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction.	Observers.
Allegheny,	Pittsburgh,	847	30·183	30·820	29·610	28·6	61·0	7	3·0	28	36·0	20·3	15·7	27·5	1	6·3	9	73·2	20·7	6·17	9·4	22	2	10	19	W	Oscar D. Stewart, Sgt. Sig. Corps.
Armstrong,	Kittanning,																										Tyson Bellman.
Bedford,	Charlesville,	1,500				22·9	53·0	7	−7·5	12	30·2	14·0	16·2	29·5	13	7·0	9	77·1	16·8	4·06	9·5	11	5	11	15	NW	Rev. A. Thos. G. Apple.
Berks,	Reading— Selwyn Hall School,																										Prof. George A. Ruddle.
Berks,	Kutztown— Keystone State Normal School,																										Prof. J. H. Rohrbach.
Blair,	Hollidaysburg,	947				22·7	49·0	7	−5·0	23	32·5	13·4	19·1	35·0	13	8·0	6	73·5	15·6	5·69	16·5	11	5	15	11	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718				21·4	48·3	1	−6·0	22	28·9	13·9	15·0	27·5	23	10·5	28	76·6	14·6	2·63	13·0	7	7	8	16	NW	Charles Beecher.
Bucks,	Quakertown,	536	30·200	30·840	29·610	21·8	49·7	1	−4·2	23	30·6	13·5	17·1	29·7	1	9·5	6, 31	85·6	18·3	4·15	15·5	14	4	17	10	NW	J. L. Heacock.
Butler,	Butler,																										J. E. Forsythe.
Cameron,	Emporium,																										A. H. Boynton.
Centre,	State College— Agricultural Experiment Station,	1,191	30·210	30·857	29·814	21·1	47·0		−9·0	23	27·9	10·2	17·7	27·5	23	8·0	9	85·9	18·0	3·46	17·3	13	3	13	15	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350				21·4	52·0		−10·0	21, 22	30·4	12·4	18·0							3·52	14·0	14	3	10	18	SW	L. Ray Morgan.
Chester,	West Chester,	455	30·199	30·811	29·613	24·6	50·0	1	0·0	22	31·2	17·4	13·8	26·0	16	5·0	6			5·89		17	11	10	10	NW	Jessie C. Green, D.D.S.
Chester,	Coatesville,																										W. T. Gordon.
Clarion,	Clarion— State Normal School,	1,479				19·8	49·0		13·5	22	28·2	11·4	16·8	32·5	22	7·0	31	89·4	17·3	4·88	12·5	13	3	9	19	W	J. H. Apple, A. B.
Clearfield,	Grampian Hills,	1,450	30·028	30·598	29·608	19·2	54·0		−12·0	22	24·8	12·1	12·7	28·0	23	1·0	18			5·77	20·0	15	2	9	19	W	Nathan Moore.
Clinton,	Lock Haven— Central State Normal School,																										Prof. Wallace P. Dick.
Columbia,	Catawissa,	480				22·3	50·0		−5·5	22, 23										3·58	10·8	14					Wm. G. Yetter.
Crawford,	Meadville— Allegheny College,	1,252				23·2	54·0		−4·5	22	30·0	12·1	17·9	36·0	13	4·0	26	69·0	14·6	4·49	30·5	14	3	9	19	W	Prof. J. H. Montgomery.
Cumberland,	Carlisle— Dickinson College,																										Charles F. Himes, Ph. D.
Cumberland,	Carlisle,	480				20·3	40·5		1·0	23										3·30	10·5	13	7	11	13	—	J. E. Pague.
Dauphin,	Harrisburg,																										Zenos J. Gray, M. D.
Delaware,	Swarthmore— Swarthmore College,	190	30·176	30·847	29·678	25·8	53·3		2·0	22	31·5	18·2	13·3	28·7	1	5·0	6	76·4	[illegible]	4·57	—	12	9	10	12	N	Prof. Susan J. Cunningham.
Elk,	Ridgway,																										Joe Messinger.
Erie,	Erie,	681	30·192	30·860	29·490	21·0	55·0		−6·0	22	31·6	13·4	18·2	34·0	13	7·0	28	83·0	[illegible]	2·79	13·0	24	1	10	20	NW	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·136	30·683	29·623	30·4	[illegible]		2·0	22	39·0	22·4	16·6	27·0	4	3·0	8	76·2	[illegible]	5·69	5·5	9	5	12	14	SW	Wm. Hunt.
Forest,	Tionesta,																										Robert L. Haslet.
Franklin,	Chambersburg— Wilson Female College,	618	30·237	30·830	29·780	22·8	43·5		1·0	23	32·0	15·4	16·6	28·0	15	8·0	6, 7	75·6	[illegible]	2·12	13·0	8	8	11	12	—	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875				24·3	47·[illegible]		2·0	12, 22	33·0	16·5	16·5	28·0	30	6·0	18	78·2	[illegible]	4·12	10·5	12	8	10	13	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650				22·0	47·0		7·5	22, 23	32·0	14·1	17·9	31·0	14	7·0	7	86·5	[illegible]	6·04	11·7	12	13	8	10	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350				23·8	58·0		−5·5	22	32·3	13·7	18·6	47·0	13	7·0	18, 31	88·1	[illegible]	6·75	13·4	17	3	9	19	SW	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750				20·6	50·0		[illegible]	23	24·8	12·8	17·0	27·0	11, 13	9·5	26	82·1	13·2	4·36	14·8	13	9	10	12	W	T. F. Heebner, M. D.
Lancaster,	Lancaster— Franklin and Marshall College,	413	30·227	30·833	29·733	23·6	47·0		−5·0	22	31·1	16·1	15·0	24·5	30	6·5	17	77·8	[illegible]	4·79	15·2	13	5	13	13	W	A. M. Schmidt, A. B.
Lawrence,	New Castle,	932				23·1	54·0		−12·0	29	31·0	14·7	16·3	32·0	29	1·0	8	87·3	[illegible]	2·77	4·7	13	4	11	16	NW	Wm. T. Butz.
Lebanon,	Lebanon,*	480				18·7	40·8		−4·5	23	26·0	10·8	15·2	28·9	20	6·3	17	75·5	[illegible]	1·04	11·9	8	6	8	7	NW	George W. Hayes, C.E., Ph. G.
Luzerne,	Drifton— Drifton Hospital,	1,655				18·3	44·[illegible]		[illegible]	22	29·8	9·9	19·9	30·0	13	11·0	3			3·79		9					H. D. Miller, M. D.
Lycoming,	Williamsport,																										E. H. Baker.
McKean,	Smethport,																										Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	30·142	30·909	29·483	20·4	53·6		−14·[illegible]	29	29·6	12·0	17·6	31·5	23	4·2	19	84·7	[illegible]	3·50	11·4	21	1	9	21	NW	Prof. S. H. Miller.
Monroe,	Stroudsburg,																										N. C. Miller, M. D.
Montgomery,	Pottstown,	150				24·3	47·[illegible]		[illegible]	23	30·0	19·1	10·9	21·0	20	5·0	6	74·5		4·31	—	10	9	11	11	NW	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	30·142	30·678	29·641	23·0	52·[illegible]		−4·[illegible]	23	29·[illegible]	16·0	13·0	31·1	1	4·0	31	73·0		5·09		8				W	Lerch & Rice.
Northumberland,	Shamokin,	743				22·2	50·[illegible]		[illegible]	23	32·7	15·3	17·4	29·0	23	10·0	1, 19	81·0		2·57		11	5	14	12	NW	G. R. Hanley.
Perry,	New Bloomfield,	400				22·5	44·0		[illegible]	23	29·2	15·8	13·4	33·0	20	4·0	18			2·17	12·8	9	11	9	11	W	Frank Mortimer.
Philadelphia,	Philadelphia,	117	30·202	30·830	29·620	28·0	50·2		2·4	22	35·4	20·2	15·2	29·0	11	8·3	9	71·4		4·30	6·5	15	6	14	11	NW	Luther M. Dey, Sgt. Sig. Corps.
Pike,	Blooming Grove,	800				19·4	44·[illegible]		[illegible]	23										2·90	19·0	15				W	John Grathwohl.
Schuylkill,	Girardville,	1,030	30·137	30·701	29·713	23·5	47·[illegible]		[illegible]	22	29·9	12·8	17·1	33·0	13	5·0	31			3·50	11·8	9	9	10	12	NW	E. C. Wagner.
Somerset,	Somerset,	2,250				22·2	[illegible]		[illegible]	22	34·2	12·3	21·9	38·0	22	7·0	28	85·0		6·10	25·8	16	5	8	18	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060				13·6	49·[illegible]		−14·0	22	19·6	7·0	12·6	24·0	25	4·0	9, 11, 26	68·7		6·16	41·3	12	3	11	17	NW	E. S. Chase.
Sullivan,	Bernice,†	2,300				15·6	46·0		−11·[illegible]	22	23·8	7·3	16·5	28·0	23	7·0	19	83·9		2·95	16·2	14	3	11	15	N	C. R. Claghorn.
Susquehanna,	Montrose,																										A. H. Berlin.
Tioga,	Wellsboro,	1,327	30·180	30·804	29·679	20·6	50·[illegible]		[illegible]	22	26·5	13·5	13·0							3·70	16·9	11	2	6	23	N	H. D. Deming.
Washington,	Scenery Hill,																										Jacob Gayman.
Washington,	Washington,	1,175				24·4	54·8		[illegible]	28	29·8	16·7	13·1	25·0	4	1·0	18			5·56	—	11	4	5	15	NW	Harrison Otis.
Warren,	Columbus,	1,410	30·445	30·986	29·730	17·0	[illegible]		[illegible]	21	25·3	10·5	14·8	45·0	22	1·0	8, 26			3·32	—	19	2	4	25	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100				15·5	44·5		[illegible]	21	24·8	4·8	20·0	31·0	23	5·5	9			4·38	18·2	16	6	7	18	NW	Theodore Day.
Westmoreland,	Greensburg,	1,075				26·8	57·8			22	35·5	13·5	22·0	25·8	1	9·0	16	82·2		5·06	10·6	14	2	11	18	W	H. S. Brunot.
York,	York,	385				24·4	[illegible]			22	31·3	17·5	13·8	25·0	16, 20	4·5	31	75·6	[illegible]	2·70	7·3	7	9	10	12	NW	Mrs. L. H. Grenewald.

* From February 3d.
† From February 11th.

T. F. Townsend,
Sergeant Signal Corps, Assistant.

PRECIPITATION FOR JANUARY, 1888.

	Erie.	Meadville.	Greenville.	New Castle.	Pittsburgh.	Columbus.	Clarion.	Greensburg.	Uniontown.	Indiana.	Somerset.	Grampian Hills.
1	·52	. .	·42	·02	·67	·60	. .	. .	·57	1·01	1·24	·83
2	·04	. .	·10	. .	. .	. .	. .	. .	. .	. .	. .	. .
3	·06	·15	. .	. .	·12	·05	·50	. .	. .	. .	·15	. .
4	·05	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .
5	·03	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·04
6	·62	·95	·98	·50	·68	·67	·72	·65	·81	1·10	·97	·71
7	·24	. .	·50	·75	·89	·28	·83	·73	·68	1·41	·43	·74
8	·18	. .	·10	·18	·38	·13	·14	·43	·47	·33	·31	·20
9	. .	. .	·01	. .	·05	. .	. .	·61	. .	·05	·13	. .
10	·06	·14	·02	·02	·17	·05	·15	·15	·32	·15	·07	·15
11	. .	·25	·02	. .	·02	·03	. .	. .	. .	. .	. .	. .
12	·15	. .	. .	·05	·10	. .	. .	. .	. .	. .	. .	. .
13	·04	·10	·36	·40	·85	·32	·73	·87	·67	·42	1·18	·90
14	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
15	·15	·30	·34	·47	·80	·29	·63	·56	·71	·86	·25	·77
16	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
17	·15	·10	·19	. .	·23	·22	. .	·35	·27	·05	. .	·33
18	·08	·15	·01	·05	·09	·02	·30	·10	·07	·05	·25	·05
19	·03	·30	·03	. .	·17	02	. .	. .	. .	. .	·13	. .
20	·03	·15	·03	·06	·08	·03	·06	·02	·05	·17	·01	·10
21	. .	. .	·01	. .	·03	. .	. .	. .	·05	. .	. .	. .
22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	·04	. .	·04	·08	·03	·03	·10	·01	. .	·05	. .	. .
24	·02	·30	·01	. .	. .	·03	. .	. .	. .	·05	. .	·05
25	·18	·60	·21	·15	·46	·22	·12	·03	·42	·60	·45	·30
26	·02	·50	·06	·04	·08	·30	·50	·53	·10	·25	·51	·44
27	·08	·50	·05	. .	·16	. .	. .	·02	·15	. .	·10	.
28	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	. .	·01	. .	. .	. .	·10	. .	. .	. .	. .	·16
30	. .	. .	. .	. .	·01	. .	. .	. .	. .	·01	. .	. .
31	·01	. .	. .	. .	·10	·01	. .	. .	·35	·19	·22	. .
	2·79	4·49	3·50	2·77	6·17	3·32	4·88	5·06	5·69	6·75	6·40	5·77

	Phillipsburg.	Hollidaysburg.	Charlesville.	State College.	Huntingdon.	McConnellsburg.	Chambersburg.	New Bloomfield.	Carlisle.	York.	Wysox.	Eagles Mere.	Bernice.†
1	·84	1·07	1·30	·57	2·00	1·69	. .	1·06	1·39	1·40	·06	·30	·10
2	·06	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·02	·01
3	·04	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
4	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
6	·18	·95	·27	·20	·33	·12	·15	·01	·12	·04	1·13	·34	·60
7	·73	·31	·22	·54	·44	·33	·27	·06	·16	·21	·13	. .	·13
8	. .	. .	·09	·32	·42	·11	·15	·06	·03	·15	. .	. .	·16
9	. .	·15	. .	. .	·13	·19	·05	·05	·01	. .	. .	. .	. .
10	·36	. .	. .	·13	. .	. .	. .	. .	·03	. .	. .	·31	·07
11	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	. .	. .	. .	. .	. .	·90	. .	. .	. .	. .	. .	. .	. .
13	·06	1·28	1·38	·66	1·40	·10	·50	·45	·72	·30	. .	2·17	·52
14	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
15	1·08	·22	·03	·27	·03	·05	. .	. .	·01	·08	. .	·63	·42
16	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·01
17	.	·44	·26	·10	·43	·23	·32	·20	·18	. .	·68	·33	·30
18	. .	. .	. .	·01	·25	. .	. .	. .	·02	. .	. .	·23	·15
19	·02	. .	·02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
21	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	·04	·05	. .	·01	. .	. .	. .	. .	. .	. .	. .	·08	. .
24	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
25	. .	1·07	·31	·50	·50	·35	·45	·50	·48	·52	·40	1·30	·30
26	·04	. .	. .	. .	. .	. .	. .	. .	·05	. .	·10	·40	·05
27	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
28	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
29	. .	·01	·06	·08	·06	·15	·23	·08	·10	. .	. .	. .	. .
30	·06	. .	. .	. .	. .	. .	. .	. .	. .	. .	·13	. .	. .
31	. .	·14	·12	·07	·05	·10	. .	. .	. .	. .	. .	·05	·13
	3·52	5·69	4·04	3·46	6·04	4·32	2·12	2·47	3·30	2·70	2·63	6·16	2·95

	Shamokin.	Girardville.	Lebanon.*	Lancaster.	Scranton.	Pottstown.	West Chester.	Dyberry.	Blooming Grove.	Quakertown.	Swarthmore.	Philadelphia.
1	·50	1·25	. .	1·60	1·25	1·50	2·22	1·70	·30	1·65	2·02	1·58
2	. .	. .	. .	·50	. .	. .	·08	. .	. .	·09	·08	·07
3	·01	. .	. .	. .	·05	. .	. .	. .	. .	·02	. .	. .
4	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .
5	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
6	·32	·53	. .	·25	·65	·40	·13	·32	·10	·17	. .	·10
7	·22	·37	. .	·02	. .	·25	·09	·06	. .	·21	·22	·06
8	·33	. .	. .	·10	·22	. .	·36	·19	·30	·11	·22	·17
9	. .	·09	. .	·60	·02	. .	·09	. .	. .	. .	·02	·03
10	. .	. .	. .	·11	·02	·25	·31	·18	·30	·20	·29	·20
11	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
13	·30	·41	·65	·70	·68	·40	1·11	·45	·30	·70	·92	·97
14	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
15	·35	·18	·10	·10	·32	·08	·12	·40	·40	·09	·02	·16
16	·10	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .
17	. .	·24	·18	·09	·20	·38	·37	·29	. .	·18	·01	·20
18	. .	. .	. .	. .	·25	. .	·02	. .	·40	·25	. .	. .
19	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .
20	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
21	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
22	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
23	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
24	. .	. .	. .	. .	. .	. .	. .	·04	. .	. .	. .	. .
25	·30	·43	·59	·60	·40	·90	·80	·30	. .	·61	·72	·53
26	·13	. .	. .	. .	·20	. .	·03	·20	·80	·05	. .	·06
27	. .	. .	. .	. .	. .	. .	. .	·04	. .	. .	. .	·01
28	. .	. .	. .	. .	. .	. .	. .	·04	. .	. .	. .	. .
29	. .	. .	·05	·02	. .	. .	·03	. .	. .	. .	. .	·02
30	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	. .	. .
31	·01	. .	·06	·10	·10	·15	·11	·07	. .	·12	·05	·14
	2·57	3·50	1·64	4·79	4·36	4·31	5·89	4·38	2·90	4·45	4·57	4·30

* From February 3d. † From February 11th.

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN FOR FEBRUARY, 1888.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 29, 1888.

Two new stations have been added to the service since the last report, and several enquiries have been received from other counties. Observers are still wanted for Adams, Cambria, Carbon, Greene, Jefferson, Juniata, Lehigh, Mifflin, Snyder, Union and Wyoming. No doubt there are persons in each of these counties, keeping daily records, who would gladly take part in an organized service if the subject were brought to their attention.

Attention is called to the paragraph in the January bulletin that relates to Weather Signals.

The promptness of those observers who send in their reports immediately after the close of the month is appreciated. As the value of the weekly Crop Reports made by Observers depends almost entirely on the cancelling of such words in *italics* on the form as do not apply to the conditions of the six preceding days for which the report is made, all Observers forwarding these forms are particularly requested to cancel all *italicized* words that do not apply to the conditions of the week for which the report is made, and to mail them so that they will reach this city by 4 P. M. on Saturday of each week.

The Committee on Meteorology of the FRANKLIN INSTITUTE,
W. P. TATHAM, *Chairman.*

REVIEW FOR FEBRUARY, 1888.

TEMPERATURE.

The mean temperature for February, for the State, was 28°·4, which is about 1° below the normal.

Fayette, Allegheny and Philadelphia report the highest monthly means, and Wayne, Sullivan, Warren and Erie the lowest.

The warmest period of the month prevailed on the 14th and 20th. Uniontown reports 63°; Pittsburgh, 61°; Indiana, 61°, and Greensburg, 60°. The cold wave of the 10th was general throughout the State, and the following low temperatures were reported: Dyberry, —31°; Columbus, —25°; Blooming Grove, —22°; Tionesta, —19°; Bernice, —19°; Wysox, —18°·5; Phillipsburg, —18°; Scranton, —17°; Eagles Mere, —16°, and Clarion, —16°. In some localities the lowest temperatures noted occurred on the 16th.

ATMOSPHERIC PRESSURE.

The mean barometer, 30·12, is slightly below the normal. The highest occurred on the 15th, and was accompanied by a cold wave. The lowest pressure was on the 25th, and was attended by heavy rains. Heavy snow and rain occurred during the depression of the 8th, and heavy rain with that of the 4th.

PRECIPITATION.

The average precipitation, including rain and melted snow, was 2·50 inches, which is from a half to one inch below the normal. The total precipitation in Eastern Pennsylvania was nearly double that in the western portion. Wellsboro reports 4·54 inches; West Chester, 4·97 inches; Quakertown, 4·26 inches, and Bernice, 4·46 inches, while Phillipsburg had but 0·89 inches, and Washington, 0·91 inches.

SNOWFALL.

The average snow was about 7 inches, and most of it fell during the first half of the month. The greatest totals reported were 18 inches at Bernice, 14·7 inches at Dyberry, and 14 inches at Eagles Mere. Very little snow was left on the ground at the end of the month.

WIND AND WEATHER.

High winds, causing damage, occurred at Bernice, 20th; Uniontown, 24th; Clarion, 24th; Catawissa, 25th; Scranton, 25th; Somerset, 25; Greensburg, 25th; Lebanon, 25th.

Prevailing wind direction for the month, Northwest.

Average number of clear days, 7; fair days, 11; cloudy days, 11; rainy days, 9.

MISCELLANEOUS PHENOMENA.

Auroras.—Bernice, 8th; Eagles Mere, 8th.

Solar Halos.—Charlesville, 1st, 14th, 19th; Eagles Mere, 11th, 14th, 17th, 19th, 21st, 28th; Wellsboro, 17th, 28th.

Lunar Halos.—Catawissa, 3d, 21st; Dyberry, 17th; Bernice, 21st; McConnellsburg, 17th; Carlisle, 17th, 19th; Indiana, 20th; Charlesville, 17th, 22d; West Chester, 19th; Somerset, 17th; Chambersburg, 17th; Lebanon, 19th, 21st; Greenville, 17th; New Castle, 21st; Washington, 17th, 23d; Clarion, 21st; Eagles Mere, 19th, 20th.

Lunar Coronæ.—Dyberry, 1st; Huntingdon, 21st; Charlesville, 28th; York, 22d; Girardville, 26th; Tionesta, 21st; Greensburg, 17th; Lebanon, 17th, 19th, 21st, 23d, 28th; Indiana, 27th.

Polar Bands.—Catawissa, 12th.

Zodiacal Lights.—Dyberry, 2d, 3d, 6th.

Thunder Storm.—Greensburg, 20th.

MIGRATION OF BIRDS.

Blue Birds.—Charlesville, 19th; Quakertown, 22d; Greenville, 22d; Dyberry, 24th.

Robins.—Dyberry, 19th; Greenville, 22d; Quakertown, 26th.

Black Birds.—Quakertown, 26th.

CROPS.

Winter wheat has been well protected by snow, and is reported in good condition.

T. F. T.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.

Displayman.	*Station.*
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.

RVICE FOR FEBRUARY, 1888.

Precipitation.			Number of Days.			Wind.	
Total Inches.	Total Depth of Snow (inches).	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	Prevailing Direction.	Observers.
·74	—	12	5	15	9	NW	Oscar D Stewart, Sgt. Sig. Corps.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Tyson Heilman.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Hon Hartford P. Brown.
·92	8·5	9	6	13	10	NW	Rev. A. Thos. G. Apple.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. George A. Ruddle.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. J. H. Rohrbach.
·17	. . .	9	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
·12	2·0	6	14	5	10	W	Prof. J. A. Stewart.
·25	7·1	8	5	10	14	NW	Charles Beecher.
·26	. . .	13	6	18	8	NE	J. L. Heacock.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. E. Forsythe.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	T B. Lloyd.
·72	4·7	10	6	11	12	W	Prof. Wm. Frear.
·89	6·0	. . .	. . .	. . .	. . .	SW	L. Ray Morgan.
·97	4·0	15	12	9	8	NW	Jesse C. Green, D.D.S.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	W. T. Gordon.
·79	. . .	6	4	15	10	SW	J. H. Apple, A.B.
·73	3·0	8	11	10	8	W	Nathan Moore.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. John A. Robb.
·03	9·2	9	12	7	10	NW·	Robert M. Graham.
·55	16·5	7	. . .	. . .	. . .	. . .	Prof. J. H. Montgomery.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. Charles F. Himes, Ph.D.
·37	7·6	13	9	11	9	W	J. E. Pague.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Zenos J. Gray, M.D.
2·74	3·5	6	10	10	9	NW	Prof Susan J. Cunningham.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Joe Messinger.
·66	. . .	9	6	12	11	S, NW	Peter Wood, Sgt Sig. Corps.
·26	1·5	5	12	8	9	NW, SW	Wm. Hunt.
. . .	. . .	. . .	10	10	9	SW	Robert L. Haslet.
3·95	4·5	8	12	9	8	. . .	Miss Mary A. Ricker.
·76	. . .	10	11	11	7	W	Thomas F. Sloan.
1·83	5·7	9	7	13	9	W	Prof. W. J. Swigart.
1·84	. . .	10	7	11	11	W, SW	Prof. Albert E Maltby.
3·25	11·3	8	9	9	11	NW	T. F. Heebner, M.D.
2·52	8·0	8	5	10	14	W	A. M. Schmidt, A.B.
1·83	2·6	7	3	17	9	NW	Wm. T. Butz.
3·89	8·7	13	9	10	10	NW, NE	George W. Hayes, C.E., Ph.G.
2·63	. . .	5	. . .	. . .	. . .	NW	H. D. Miller, M.D.
1 30	. . .	. . .	. . .	. . .	. . .	NW	E. H. Baker.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Armstrong & Brownell.
1·63	3·0	12	5	9	15	NW	Prof S. H. Miller.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	N. C. Miller, M.D.
4·08	5·5	9	10	11	8	NW	Charles Moore, D.D.S.
3·50	. . .	7	.	. .	. . .	W	Lerch & Rice.
2·61	6·2	10	7	13	9	W	G. R. Hanley.
2·92	8·2	8	14	5	10	W	Frank Mortimer.
2·57	2·1	13	6	16	7	NW	Luther M. Dey, Sgt. Sig. Corps.
2·47	12·0	6	. . .	. . .	. . .	W	John Grathwohl.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	D. W. Butterworth.
3·45	11·7	9	11	9	9	NW	E. C Wagner.
1·34	3·8	8	7	8	14	NW, SW	W. M. Schrock.
3·87	14·0	7	4	11	14	SW	E. S. Chase.
4·46	18·0	13	5	12	12	W	C R. Claghorn.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	A. H. Berlin.
4·54	5·0	6	2	11	16	N	H. D. Deming.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. N. P. Kinsley.
. . .	. . .	. . .	. . .	. . .	. . .	. . .	Jacob Gayman.
0·01	. . .	8	2	14	13	NW, SW	Harrison Otis.
2·03	. . .	11	3	14	12	SW	Wm. Loveland.
3·07	14·7	13	3	12	14	NW	Theodore Day.
1·28	3·7	8	2	17	10	SW	H. S. Brunot.
2·20	7·8	11	9	10	10	NW	Mrs. L. H. Grenewald.

T. F. TOWNSEND, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for February, 1888.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Date.	Least.	Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Total Depth of Snow (inches).	Number of Days Rainfall.	Number of Days. Clear.	Fair.	Cloudy.	Wind. Prevailing Direction.	Observers.
	Pittsburgh,	847	30·056	30·810	29·410	34·1	61·0	[illegible]	1·1	10	43·5	25·9	17·6	33·0	16	6·6	1	71·0	25·3	1·74	—	12	5	15	9	NW	Oscar D. Stewart, Sgt. Sig. Corps.
	Kittanning,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Tyson Heilman.
	Rochester,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Hon. Hartford P. Brown.
	Charlesville,	1,500	...	...	...	29·1	58·5	14	0·5	10	39·9	20·0	19·9	39·5	13	5·0	4	75·4	21·8	1·92	8·5	9	6	13	10	NW	Rev. A. Thos. G. Apple.
	Reading— Selwyn Hall School,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. George A. Ruddle.
	Kutztown— Keystone State Normal School,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. H. Rohrbach.
	Altoona,*	1,209	...	...	...	34·7	59·0		−2·0	10	...	...	...	...	...	...	...	72·4	27·0	1·17	...	9	...	...	...	...	Dr. Charles B. Dudley.
	Hollidaysburg,	947	...	...	...	29·5	58·0	14	−9·0	10	41·0	17·9	23·1	43·0	14	8·0	12	70·5	20·6	2·12	2·0	6	14	5	10	W	Prof. J. A. Stewart.
	Wysox,	718	...	...	...	27·0	50·5		−18·5	10	36·2	17·0	19·2	42·0	15	9·5	27	73·9	19·8	1·25	7·1	8	5	10	14	NW	Charles Beecher.
	Quakertown,	536	30·130	30·680	29·560	27·3	50·0		−4·0	16	37·4	17·2	20·2	42·0	15	10·0	25	83·6	22·0	4·26	...	13	6	18	8	NE	J. L. Heacock.
	Butler,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
	Emporium,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	T. B. Lloyd.
	State College— Agricultural Experiment Station,	1,191	30·161	30·792	29·575	28·5	56·0		−13·0	10	36·1	10·6	19·5	40·5	15	7·5	5	84·9	23·4	1·72	4·7	10	6	11	12	W	Prof. Wm. Frear.
	Philipsburg,	1,350	...	...	...	28·1	55·0		−18·0	12	39·6	16·5	23·1	...	...	...	...	...	...	0·89	6·0	...	...	...	...	SW	L. Ray Morgan.
	West Chester,	455	30·110	30·639	29·518	30·7	53·5		−1·0	16	38·4	22·6	15·8	34·0	15	5·0	12	72·0	22·0	4·97	4·0	15	12	9	8	NW	Jesse C. Green, D.D.S.
	Coatesville,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	W. T. Gordon.
	Clarion— State Normal School,	1,530	...	...	...	26·7	51·0		−16·0	10	36·0	16·7	19·3	36·0	10	9·0	1	83·0	21·8	1·79	...	6	4	15	10	SW	J. H. Apple, A. B.
	Grampian Hills,	1,450	...	...	...	25·5	54·0		−14·0	10	34·2	17·6	16·6	34·0	16	4·0	4, 5	...	...	1·73	3·0	8	11	10	8	W	Nathan Moore.
	Lock Haven,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. John A. Robb.
	Catawissa,	491	...	...	...	30·5	53·0		−9·0	10	38·0	19·5	18·5	46·0	17	6·0	26, 27	71·5	21·5	2·03	9·2	9	12	7	10	NW	Robert M. Graham.
	Meadville— Allegheny College,	1,252	30·120	30·866	29·345	31·5	52·0		−8·0	10	38·6	19·4	19·2	35·0	8	3·0	2	74·7	24·2	1·55	16·5	7	...	...	...	...	Prof. J. H. Montgomery.
	Carlisle— Dickinson College,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Charles F. Himes, Ph.D.
	Carlisle,	480	...	...	...	27·4	50·3		0·0	16	...	...	...	...	...	...	...	78·8	21·4	1·37	7·6	13	9	11	9	W	J. E. Pague.
Dauphin,	Harrisburg,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Zenos J. Gray, M.D.
Delaware,	Swarthmore— Swarthmore College,	190	30·093	30·469	29·593	31·2	55·2		1·9	16	39·4	24·1	15·3	35·5	15	3·1	12	77·0	24·1	·74	3·5	6	10	10	9	NW	Prof. Susan J. Cunningham.
Elk,	Ridgway,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Joe Messinger.
Erie,	Erie,	681	30·070	30·820	29·370	26·0	51·[illegible]		−8·0	10	37·8	18·1	19·7	37·0	16	6·5	18	77·0	19·0	1·66	...	9	6	12	11	S, NW	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·057	30·591	29·492	35·2	[illegible]		5·0	10	44·6	26·7	17·9	35·0	19	4·0	26	85·0	31·0	1·26	1·5	5	12	8	9	NW, SW	Wm. Hunt.
Forest,	Tionesta,	1,058	...	...	...	25·8	[illegible]		−19·0	10	37·6	15·2	22·4	40·0	10	9·0	4, 26	71·0	18·0		...	...	10	10	9	SW	Robert L. Haslet.
Franklin,	Chambersburg— Wilson Female College,	618	30·138	30·531	29·632	26·1	51·[illegible]		0·0	10	38·2	17·4	20·8	39·0	17	9·0	7, 12	85·7	21·1	3·95	4·5	8	12	9	8	...	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875	...	...		30·9	[illegible]	14	3·0	10	41·7	21·5	20·2	43·0	14	4·0	4	76·9	23·8	2·76	...	10	11	11	7	W	Thomas F. Sloan.
Huntingdon, ‡	Huntingdon— The Normal College,	650	...	...	...	28·5	[illegible]	14	−11·0	10	41·3	17·0	24·3	46·0	14	9·5	4	76·6	20·2	1·83	5·7	9	7	13	9	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	29·6	61·[illegible]		−4·5	10	38·4	19·4	19·0	37·0	16	7·5	26	86·3	24·2	1·84	...	10	7	11	11	W, SW	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750	...	...	...	26·7	[illegible]		−17·0	10	38·0	15·8	22·2	44·0	15	13·0	5	85·8	21·2	3·25	11·3	8	9	9	11	NW	T. F. Heebner, M.D.
Lancaster,	Lancaster— Franklin and Marshall College,	413	30·143	30·682	29·560	28·7	[illegible]		−2·3	16	38·5	20·0	18·5	37·4	17	5·6	7	80·0	23·3	2·52	8·0	8	5	10	14	W	A. M. Schmidt, A.B.
Lawrence,	New Castle,	932	...	...	...	30·1	[illegible]		−6·0	10	38·4	19·3	19·1	34·0	15, 16	6·0	1, 2	80·3	24·2	1·83	2·6	7	3	17	9	NW	Wm. T. Butz.
Lebanon,	Lebanon,	480	...	...	...	27·8	4[illegible]		−1·5	9	37·5	18·9	18·6	41·3	17	6·1	7, 12	80·7	22·3	1·89	8·7	13	9	10	10	NW, NE	George W. Hayes, C.E., Ph.G.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	25·7	[illegible]	14	−11·0	16	37·9	15·6	22·3	51·0	15	13·0	18	...	...	2·63	...	5	...	...	...	NW	H. D. Miller, M.D.
Lycoming,	Williamsport,†	...	...	...	...	20·9	[illegible]		−4·0	16	35·8	19·9	15·9	33·0	17	5·0	27	76·4	22·4	1·30	...	...	...	...	...	NW	E. H. Baker.
	Smethport,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
	Greenville— Thiel College,	1,000	30·012	30·778	29·511	26·5	51·[illegible]		−11·2	10	36·8	16·5	20·3	35·5	8	5·5	7	81·8	20·7	1·63	3·0	12	5	9	15	NW	Prof. S. H. Miller.
	Stroudsburg,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	N. C. Miller, M.D.
	Pottstown,	150	...	...	...	26·3	[illegible]		0·0	16	37·5	22·3	15·2	35·0	14, 17	1·0	4	76·1	20·1	4·03	5·5	9	10	11	8	NW	Charles Moore, D.D.S.
	Bethlehem,	360	...	...	...	28·8	[illegible]		−4·0	10	36·9	17·4	19·5	42·0	17	8·0	12	73·0	21·0	4·50	...	7	...	...	...	W	Lerch & Rice.
	Shamokin,	733	...	...	...	28·0	[illegible]	14	−10·0	10	39·1	18·2	20·9	51·0	15	11·0	7	83·7	23·2	2·61	6·2	10	7	13	9	W	G. R. Hanley.
	New Bloomfield,	[illegible]	...	...	...	26·7	[illegible]	14	−7·5	10	35·9	15·7	20·2	45·0	14	4·0	4	...		2·92	8·2	8	14	5	10	W	Frank Mortimer.
	Philadelphia,	117	30·116	30·680	29·490	34·1	[illegible]		2·5	16	41·7	26·1	15·6	31·5	15	6·6	12	70·0	24·5	2·57	2·1	13	6	16	7	NW	Luther M. Dey, Sgt. Sig. Corps.
	Blooming Grove,	800	...	...	...	25·6	[illegible]	14	−22·0	10	...	...	...	...	...	...	...	...	...	·47	12·0	6	...	...	...	W	John Grathwohl.
	Coudersport,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	D. W. Butterworth.
	Girardville,	1,030	30·120	30·710	29·480	28·0	50	14	−4·0	10	35·3	18·4	16·9	32·0	11	1·0	1	81·8	...	3·45	11·7	9	11	9	9	NW	E. C. Wagner.
	Somerset,	2,250	...	...	...	29·6	57		−6·0	10	35·6	19·9	15·7	35·5	16	4·0	28	...	25·0	1·34	3·8	8	7	8	14	NW, SW	W. M. Schrock.
	Eagles Mere,	2,060	...	...	...	22·2	44	14	−16·0	10	32·5	14·2	18·3	47·0	15	6·0	9	73·4	15·0	3·87	14·0	7	4	11	14	SW	E. S. Chase.
	Bernice,	2,200	...	...	...	23·3	43·0	4, 24	−19·0	10	33·1	13·6	13·5	44·0	15	10·5	1	80·2	17·5	4·46	18·0	13	5	12	12	W	C. R. Claghorn.
	Montrose,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	A. H. Berlin.
	Wellsboro,	1,327	30·081	30·742	29·549	26·3	55	4	−17·0	10	35·5	19·7	15·8	42·1	14	1·2	15	87·1	28·2	4·54	5·0	6	2	11	16	N	H. D. Deming.
	Franklin,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
	Scenery Hill,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Jacob Gayman.
	Washington,	1,175	...	...	...	32·5	[illegible]		2·5	10	38·9	24·4	14·5	31·0	19	2·2	1	...	...	0·91	...	8	2	14	13	NW, SW	Harrison Otis.
	Columbus,	1,410	...	...	...	24·9	[illegible]		−25·0	10	35·3	14·3	21·0	59·0	12	0·0	5	...	...	2·03	...	11	3	14	12	SW	Wm. Loveland.
	Dyberry,	1,100	...	...	...	20·9	4[illegible]	14	−31·0	[illegible]	32·6	8·1	24·5	41·0	15	4·0	4	...	...	3·07	14·7	13	3	17	14	NW	Theodore Day.
	Greensburg,	1,075	...	...	...	32·5	60		−2·0	10	42·4	23·5	18·9	34·5	10	5·0	11	80·2	27·1	1·28	3·7	8	2	17	10	SW	H. S. Brunot.
	York,	385	...	...	...	29·7	[illegible]		5·6	[illegible]	38·6	21·6	17·0	39·0	14	5·0	4	75·6	22·6	2·20	7·8	11	9	10	10	NW	Mrs. L. H. Grenewald.

*Observations taken at 12, Noon. † From 15th. ‡ Huntingdon's lowest temperature for January should read −7·5

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR FEBRUARY, 1888.

Indiana.	Somerset.	Grampian Hills.	Phillipsburg.	Hollidaysburg.	Altoona.	Charlesville.	State College.	Huntingdon.	McConnellsburg.	Chambersburg.	New Bloomfield.	Carlisle.	York.	Wysox.	Eagles Mere.	Bernice.	Catawissa.	Shamokin.	Girardville.	Lebanon.	Lancaster.	Drifton.	Scranton.	Pottstown.	West Chester.	Dyberry.	Blooming Grove.	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.
							.01																								
.48	.50	.73	.53	.41	.32	.38	.28	.19	.66	.85	.20	.60	.64	.11	.53	.28	.36	.54	.57	.68	.40	.64	.55	.70	.67	.47	.40	.73	.62	.39	.41
.18	.08	.11			.04	.03	.05	.05	.05			.02	.06	.08		.20	.07	.29	.08	.17			.05		.09	.17	.09		.13		.07
												.01				.14				.03		.04			.04	.06			.05		.02
.01		.12	.01	.21		.17	.19	.22	.19	.05	.25	.17	.02	.13	.45	.47	.20	.22	.24	.22	.09	.56	.48	.24	.21	.29		.32	.29	.05	.16
.13	.01	.04	.03		.10	.03	.05	.11	.15	.05	.15	.20	.05	.44	.43	.43	.19	.25	.12	.17	.12		.20	.20	.40	.10	.38	.12	.32	.36	.24
						.04			.05	.75	.05	.05	.12			.02	.13	.05	.09	.07	.25			.22	.21	.01		.60	.14		.10
	.10		.03	.42	.14	.42	.14	.27	.45	.15	.22	.54	.14		.29	.23	.30	.07	.36	.56	.07	.41	.42	.45	.46	.32	.70		.57		.36
.01	.03	.04	.01		.02	.04	.02		.15	.20	.15	.03	.27		.04	.07	.05	.01	.16	.13	.26			.12	.19	.01			.15	.52	.09
								.08	.03			.05	.01					.02		.01			.02		.05	.03		.12	.05		.01
.50																															
				.22																											
														.09																	
																.03									.02	.03					
.01		.21												.03																	
	.19		.11	.18	.12	.15	.49	.21	.36	.90	.60	.46	.29		1.12	1.35	.47	.70	1.11	.82	.60	.98	.86	.55	.55	1.10	.50	.80	.85		.28
			.14		.06							.03													.03				.02		
														.19																.33	
.46	.41	.45		.68	.34	.66	.48	.68	.67	1.00	1.30	1.15	.48	.18	1.01	1.18	.26	.46	.72	.77	.73		.67	1.40	1.92	.42	.40	.81	.89	1.09	.76
.02		.03	.01		.03		.01	.02				.06	.12							.25				.20	.10	.06			.18		.06
.04	.02		.01													.05				.01					.03						.01
			.01													.01															
1.84	1.31	1.73	0.89	2.12	1.17	1.92	1.72	1.83	2.76	3.95	2.92	3.37	2.20	1.25	3.87	4.46	2.03	2.61	3.45	3.89	2.52	2.63	3.25	4.08	4.97	3.07	2.47	3.50	4.26	2.74	2.57

T. F. T.

PRECIPITATION FOR FEBRUARY, 18[illegible]

Day	Erie.	Meadville.	Greenville	New Castle.	Washington	Pittsburgh.	Columbus.	Clarion.	Greensburg	Uniontown	Indiana.	Somerset.	Grampian Hills	Phillipsburg.
1														
2														
3														
4	.66	.60	.64	.63	.57	.63	.45	.70	.63	.26	.48	.50	.73	.53
5	.26		.21		.06	.05	.37	.30	.19	.13	.18	.08	.11	
6		.10	.01											
7	.01	.50	.02			.01	.02				.01		.12	.01
8	.03	.10	.12	.15	.02	.21	.23	.15	.03	.28	.13	.01	.04	.03
9														
10														
11									.03	.36		.10		.03
12											.01	.03	.04	.01
13														
14	.28		.06	.03		.01	.14	.03			.50			
15		.10			.01									
16														
17														
18			.01											
19	.02		.03								.01		.21	
20	.05		.04	.07	.16	.10	.20	.18	.05			.19		.11
21							.02							.14
22														
23														
24			.01											
25	.29		.47	.87	.02	.53	.48	.43	.32	.23	.46	.41	.45	
26	.06		.41	.03		.09	.05		.01		.02		.03	.01
27		.10		.05	.06	.11	.05		.02		.04	.02		.01
28		.05					.02							.01
29					.01									
30														
31														
Total	1.66	1.55	1.63	1.83	0.91	1.74	2.03	1.79	1.28	1.26	1.84	1.31	1.73	0.89

Day	Hollidaysburg.	Altoona.	Charlesville.	State College.	Huntingdon.	McConnellsburg.	Chambersburg.	New Bloomfield	Carlisle.	York.	Wysox.	Eagles Mere	Bernice.	Catawissa.
1				.01										
2														
3														
4	.41	.32	.38	.28	.19	.66	.85	.20	.60	.64	.11	.53	.28	.36
5		.04	.03	.05	.05	.05			.02	.06	.08		.20	.07
6									.01				.14	
7	.21		.17	.19	.22	.19	.05	.25	.17	.02	.13	.45	.47	.20
8		.10	.03	.05	.11	.15	.05	.15	.20	.05	.44	.43	.43	.19
9														
10			.04			.05	.75	.05	.05	.12			.02	.13
11	.42	.14	.42	.14	.27	.45	.15	.22	.54	.14		.29	.23	.30
12		.02	.04	.02		.15	.20	.15	.03	.27		.04	.07	.05
13					.08	.03			.05	.01				
14														
15	.22													
16														
17											.09			
18													.03	
19											.03			
20	.18	.12	.15	.49	.21	.36	.90	.60	.46	.29		1.12	1.35	.47
21		.06							.03					
22														
23														
24											.19			
25	.68	.34	.66	.48	.68	.67	1.00	1.30	1.15	.48	.18	1.01	1.18	.26
26		.03		.01	.02				.06	.12				
27													.05	
28													.01	
29														
30														
31														
Total	2.12	1.17	1.92	1.72	1.83	2.76	3.95	2.92	3.37	2.20	1.25	3.87	4.46	2.03

Day	Shamokin.	Girardville	Lebanon.	Lancaster	Drifton	Scranton	Pottstown.	West Chester.	Dyberry.	Blooming Grove	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.
1														
2														
3														
4	.54	.57	.68	.40	.64	.55	.70	.67	.47	.40	.73	.62	.39	.41
5	.20	.08	.17			.05		.09	.17	.09		.13		.07
6			.03		.04			.04	.06			.05		.02
7	.22	.24	.22	.09	.56	.48	.24	.21	.20		.32	.29	.05	.16
8	.25	.12	.17	.12		.20	.20	.40	.10	.38	.12	.32	.36	.24
9														
10	.05	.09	.07	.25			.22	.21	.01		.60	.14		.10
11	.07	.36	.56	.07	.41	.42	.45	.46	.32	.70		.57		.36
12	.01	.16	.13	.26			.12	.19	.01			.15	.52	.09
13	.02		.01			.02		.05	.03		.12	.05		.01
14														
15														
16														
17														
18								.02	.03					
19														
20	.70	1.11	.82	.60	.98	.86	.55	.55	1.10	.50	.80	.85		.28
21								.03				.02		
22														
23														
24													.33	
25	.46	.72	.77	.73		.67	1.40	1.92	.42	.40	.81	.89	1.09	.76
26			.25				.20	.10	.06			.18		.06
27			.01					.03						.01
28														
29														
30														
31														
Total	2.61	3.45	3.89	2.52	2.63	3.25	4.08	4.97	3.07	2.47	3.50	4.26	2.74	2.57

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN

FOR MARCH, 1888.

HALL OF THE FRANKLIN INSTITUTE,

PHILADELPHIA, March 31, 1888.

Observers are requested to note and report the effect of late frosts on fruits and small crops, also to be prompt in sending in their Weekly Crop Reports, which should always be mailed on Friday. On these should be entered the time of seeding, harvesting, etc. The practice of attaching to these reports brief newspaper clippings relative to crops is commendable. Particular attention should be paid to the measurement of rainfall and the recording of the time of beginning and ending. Instructions to observers should be closely studied and followed, to give the highest value to their reports.

Correspondence is requested with a view of establishing stations in the counties from which no reports are received.

The Committee on Meteorology of the FRANKLIN INSTITUTE,

W. P. TATHAM, *Chairman.*

REVIEW FOR MARCH, 1888.

TEMPERATURE.

The mean temperature for Pennsylvania for the month was 31°·1, which is from 2° to 5° below the March average. The greatest departures occurred in the eastern portions of the State. The extreme low temperatures were not absolutely lower than usual, but they were of longer duration. The unusual cold, the numerous cloudy and stormy days, the severe storm of the 11th and 12th, have all combined to make the past month exceptionally disagreeable and memorable. The minimum temperatures occurred on the 6th and 13th. The lowest are: Eagles Mere, —6°·0; Bernice, —5°·5; Drifton, —5°·0; Dyberry, —5°·0, and Montrose, —4°·0. The maxima were during the latter part of the month, most of which were noted on the 20th, 21st, 30th and 31st. The highest are Uniontown, 72°·0; Pittsburgh, 71°·5; Philadelphia, 70°·0; York, 69°·0, and New Castle, 69°·0.

ATMOSPHERIC PRESSURE.

The mean barometer of 30·02 is about ·07 below the average. The high pressures were on the 9th and 25th, and the lowest on the 21st. The latter was attended by heavy rains throughout the State.

PRECIPITATION.

The average precipitation, including rain and melted snow, was 3·55 inches.

This amount was very unevenly distributed, much the larger portion falling over the eastern section of the State, causing an excess, and leaving a deficiency in the western counties. The greatest precipitation occurred on the 11th, 12th, 21st and 26th. The largest totals for the month are West Chester, 6·39 inches; Coatesville, 6·28 inches; Philadelphia, 5·42 inches; Swarthmore, 5·34 inches, and Pottstown, 5·35 inches.

SNOWFALL.

The snowfall was variable in quantity, and ranged from a depth of 20 inches at Eagles Mere, 19 inches at Bernice, Coatesville, Girardville and Dyberry, to 2 and 3 inches at the western stations.

The greater portion of the snow fell on the 11th and 12th, and for these days Eagles Mere reports 13 inches; Dyberry, 14 inches; Girardville, 12 inches; Quakertown, 12 inches; West Chester, 10 inches; Coatesville, 10 inches; Philadelphia, 10 inches; Stroudsburg, 8 inches; Pottstown, 7 inches, and Scranton, 7 inches.

WIND AND WEATHER.

The severe storm of the 11th and 12th was most remarkable and destructive, and the people of Pennsylvania experienced very many of the inconveniences and disastrous effects of a genuine blizzard. On the night of the

11th a heavy, warm rain, which had prevailed during the day from the south-east, suddenly changed to a furious snowstorm, accompanied by intense cold, and north and northwest gales.

Telegraph wires and poles were soon prostrated, railway trains were blockaded by huge snowbanks, and all communication by wire or rail was completely cut off for three days, during which time the high winds kept the snow a moving mass, which baffled all efforts to clear the roads and re-establish communication. At Philadelphia the wind attained a maximum velocity of 66 miles per hour. Reports show higher velocities along the coast in the track of the storm centre.

MISCELLANEOUS PHENOMENA.

Auroras.—Quakertown, 30th.

Solar Halos.—Lebanon, 10th; York, 10th; Eagles Mere, 5th, 25th, 27th, 31st; Dyberry, 29th; Stroudsburg, 25th; Charlesville, 10th, 27th, 30th.

Lunar Halos.—Lebanon, 19th; Indiana, 23d; Huntingdon 18th, 19th; Hollidaysburg, 19th, 20th; Grampian Hills, 24th; Girardville, 24th; Eagles Mere, 19th, 24th; Dyberry, 19th; Carlisle, 18th, 19th; Charlesville, 20th, 23d; Catawissa, 19th, 24th; Bernice, 24th; Washington, 24th, 26th; Greenville, 20th, 23d, 24th; York, 20th, 23d; Clarion, 20th, 23d, 24th; Lancaster, 14th, 18th, 19th, 23d; State College, 19th, 24th; Quakertown, 24th; Somerset, 23d; Shamokin, 24th; New Castle, 19th, 23d; Stroudsburg, 24th; Swarthmore, 19th, 24th.

Lunar Coronæ.—Lebanon, 19th, 23d; Huntingdon, 23d; Eagles Mere, 18th; Dyberry, 5th, 19th; Charlesville, 23d; Greenville, 18th; Clarion, 18th; Somerset, 20th, 24th, 26th; Shamokin, 18th; Stroudsburg, 19th, 23d.

Parhelia.—Eagles Mere, 15th; Dyberry, 15th; Clarion, 30th.

Zodiacal Lights.—Indiana, 5th; Dyberry, 4th, 9th.

Thunder Storms.—In nearly all parts of the State on 21st.

T. F. T.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office, ...	Philadelphia.
Wanamaker & Brown, ...	"
Pennsylvania Railroad Company, ...	"
Continental Brewing Company, ...	"
Samuel Simpson, ...	"
B. T. Babbitt, ...	"
Western Meat Company, ...	"
Neptune Laundry, ...	"
Chester Oil Company, ...	Chester.
C. W. Burkhart, ...	Shoemakerville.
A. N. Lindenmuth, ...	Allentown.
C. B. Whitehead, ...	Bradford.
Capt. Geo. R. Guss, ...	West Chester.
Werner & Son, ...	Emporium.

Displayman.	*Station.*
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.

r Service for March, 1888.

County	Precipitation. Total Inches.	Precipitation. Total Depth of Snow (inches).	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction.	Observers.
Allegheny,	2·51	. . .	15	4	13	14	NW	Oscar D. Stewart, Sgt. Sig. Corps.
Armstrong,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Tyson Heilman.
Beaver,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Hon. Hartford P. Brown.
Bedford,	3·42	10·9	14	6	14	11	NW	Rev. A. Thos. G. Apple.
Berks,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. George A. Ruddle.
Berks,	3·65	9·0	9	9	. . .	. . .	. . .	Prof. J. H. Rohrbach.
Blair,	1·75	. . .	11	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
Blair,	2·55	. . .	7	14	8	9	W	Prof. J. A. Stewart.
Bradford,	2·07	8·0	10	8	7	16	NW	Charles Beecher.
Bucks,	4·94	15·3	14	8	11	12	NW	J. L. Heacock.
Butler,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. E. Forsythe.
Cameron,	2·88	. . .	7	7	13	11	NW	T. B. Lloyd.
Centre,	2·85	. . .	10	7	10	14	W	Prof. Wm. Frear.
Centre,	2·06	. . .	13	5	12	14	NW	L. Ray Morgan.
Chester,	6·39	13·3	17	13	8	10	NW	Jesse C. Green, D.D.S.
Chester,	6·28	18·5	15	10	12	9	W	W. T. Gordon.
Clarion,	. . .	. . .	. . .	7	12	12	SE	Rev. W. W. Deatrick, A.M.
Clarion,	. . .	. . .	. . .	4	12	15	NW	J. H. Apple, A.B.
Clearfield,	3·00	8·0	8	3	16	12	NW	Nathan Moore.
Clinton,	2·33	7·0	9	8	11	12	W	Prof. John A. Robb.
Columbia,	2·59	6·0	10	11	10	10	NW	Robert M. Graham.
Crawford,	. . .	. . .	. . .	. . .	. . .	. . .	N, W	Prof. J. H. Montgomery.
Cumberland,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. Charles F. Himes, Ph.D.
Cumberland,	2·91	5·5	13	7	12	12	W	J. E. Pague.
Dauphin,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Zenos J. Gray, M.D.
Delaware,	5·41	. . .	10	12	8	11	NW	Prof. Susan J. Cunningham.
Elk,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Joe Messinger.
Erie,	2·04	. . .	16	5	14	12	W	Peter Wood, Sgt. Sig. Corps.
Fayette,	3·00	7·0	9	7	15	9	NW	Wm. Hunt.
Forest,	. . .	. . .	. . .	5	8	18	N	Robert L. Haslet.
Franklin,	1·72	. . .	9	. . .	. . .	. . .	. . .	Miss Mary A. Ricker.
Fulton,	3·76	8·0	11	12	10	9	N, W	Thomas F. Sloan.
Huntingdon,	3·26	5·5	10	11	12	8	W	Prof. W. J. Swigart.
Indiana,	3·34	2·5	14	5	9	17	W	Prof. Albert E. Maltby.
Lackawanna,	3·01	11·5	7	9	4	18	NW	T. F. Heebner, M.D.
Lancaster,	4·50	12·9	11	9	10	12	W	A. M. Schmidt, A.B.
Lawrence,	2·01	2·0	7	1	11	19	NW	Wm. T. Butz.
Lebanon,	4·08	7·5	15	13	8	10	NW, SW	George W. Hayes, C.E., Ph G.
Luzerne,	3·11	. . .	7	7	9	15	NW	H. D. Miller, M.D.
Lycoming,	3·09	4·1	7	5	13	13	W	E. H. Baker.
McKean,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Armstrong & Brownell.
Mercer,	1·92	3·0	14	3	12	16	NW	Prof S. H. Miller.
Monroe,	3·62	13·5	10	13	8	10	NW	N. C. Miller, M.D.
Montgomery,	5·35	12·0	10	14	6	11	NW	Charles Moore, D.D.S.
Northampton	3·84	. . .	7	11	8	12	NW	Lerch & Rice.
Northumberl	3·02	1·0	9	9	13	9	NW	G. R. Hanley.
Perry,	3·95	7·5	6	12	8	11	W	Frank Mortimer.
Philadelphia,	5·42	12·1	14	9	10	12	NW	Luther M. Dey, Sgt. Sig. Corps.
Pike,	. . .	. . .	8	. . .	. . .	. . .	N	John Grathwohl.
Potter,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	D. W. Butterworth.
Schuylkill,	4·35	19·0	10	9	11	11	NW	E. C. Wagner.
Somerset,	3·25	5·5	11	4	9	18	NW, SW	W. M. Schrock.
Sullivan,	4·34	20·0	7	8	10	13	NW	E. S. Chase.
Sullivan,	3·63	19·0	19	7	9	15	NW	C. R. Claghorn.
Susquehanna,	. . .	14·4	. . .	10	7	14	NW	A. H. Berlin.
Tioga,	3·60	10·2	9	2	8	21	NW	H. D. Deming.
Venango,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Prof. N. P. Kinsley.
Washington,	1·58	. . .	. . .	5	10	16	S	Jacob Gayman.
Washington,	3·32	. . .	12	3	10	18	NW	Harrison Otis.
Warren,	1·74	. . .	15	7	8	16	SW	Wm. Loveland.
Wayne,	4·01	18·7	15	8	5	18	NW	Theodore Day.
Westmorelan	3·77	. . .	12	5	9	17	W	H. S. Brunot.
York,	3·78	9·5	16	12	8	11	NW	Mrs. L. H. Grenewald.

*Observat

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for March, 1888.

County.	Station.	Elevation above Sea Level (feet).	Barometer.			Temperature.												Relative Humidity.	Dew Point.	Precipitation.			Number of Days.			Wind.	Observers.
			Mean.	Highest.	Lowest.	Mean.	Maximum: Highest.	Maximum: Date.	Minimum: Lowest.	Minimum: Date.	Mean of Maximum.	Mean of Minimum.	Daily Range: Mean.	Daily Range: Greatest.	Date.	Least.	Date.			Total Inches.	Total Depth of Snow (inches).	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	Prevailing Direction.	
Allegheny,	Pittsburgh,	847	30·082	30·480	29·160	36·3	71·5		9·1	13	46·3	27·5	18·8	36·0	19	8·4	13	71·2	27·3	2·51	...	15	4	13	14	NW	Oscar D. Stewart, Sgt. Sig. Corps.
Armstrong,	Kittanning,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Tyson Heilman.
[illegible]	Rochester,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Hon. Hartford P. Brown.
[illegible]	Charlesville,	1,500	...	...	...	31·8	67·0		1·0	6	41·5	23·0	18·5	35·0	18	3·0	25	72·0	24·0	3·42	10·9	14	6	14	11	NW	Rev. A. Thos. G. Apple.
[illegible]	Reading— Selwyn Hall School,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. George A. Ruddle.
[illegible]	Kutztown— Keystone State Normal School,	1,500	...	...	...	29·9	59·6		2·0	13	38·4	23·9	14·5	28·0	4	3·5	2	...	...	3·65	9·0	9	9	...	...	...	Prof. J. H. Rohrbach.
[illegible]	Altoona,*	1,209	30·252	30·699	29·742	35·7	65·5		4·0	13	46·1	25·6	20·5	39·0	12	10·5	8	73·3	28·0	1·75	...	11	...	...	...	...	Dr. Charles B. Dudley.
[illegible]	Hollidaysburg,	947	...	...	...	31·8	78·0		2·0	7	42·1	20·3	21·8	36·0	18	6·0	13	69·6	...	2·55	...	7	14	8	9	W	Prof. J. A. Stewart.
[illegible]	Wysox,	718	...	...	...	30·6	65·0		2·0	13	40·4	21·9	18·5	43·2	19	3·0	7	74·1	23·0	2·07	8·0	10	8	7	16	NW	Charles Beecher.
[illegible]	Quakertown,	536	30·090	30·540	29·410	30·6	65·0		2·0	13	40·6	21·5	19·1	32·0	19	9·0	26	80·5	24·7	4·04	15·3	14	8	11	12	NW	J. L. Heacock.
[illegible]	Butler,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
[illegible]	Emporium,	1,030	...	...	...	31·4	61·0		1·0	24	41·6	22·9	18·7	40·0	19	9·0	2	69·2	22·4	2·88	...	7	7	13	11	NW	T. B. Lloyd.
[illegible]	State College— Agricultural Experiment Station,	1,191	30·134	30·537	29·365	30·5	58·0		−1·5	13	38·2	17·8	20·4	32·5	19	12·0	5, 12	81·4	24·0	2·85	...	10	7	10	14	W	Prof. Wm. Frear.
Centre,	Philipsburg,	1,350	...	...	...	30·1	66·0		0·0	13	43·2	22·1	21·1	41·0	9	2·0	20	...	...	2·06	...	13	5	12	14	NW	L. Ray Morgan.
[illegible]	West Chester,	455	30·077	30·557	29·390	32·6	67·5		6·0	13	40·8	24·0	16·8	28·0	30	8·0	2	68·0	23·4	6·89	11·3	17	13	8	10	NW	Jesse C. Green, D.D.S.
[illegible]	Coatesville,	380	...	...	...	32·3	68·5		−3·0	6	41·4	23·2	18·2	41·5	31	3·5	...	...	...	6·28	18·5	15	10	12	9	W	W. T. Gordon.
[illegible]	Rimersburg,	1,500	...	...	...	30·1	66·0		0·0	13	36·7	23·0	13·7	26·0	19	4·0	13	...	...	...	...	...	7	12	12	SE	Rev. W. W. Deatrick, A.M.
[illegible]	Clarion— State Normal School,	1,530	...	...	...	25·7	66·0		1·0	13	36·2	16·4	19·8	40·0	19	6·0	13	83·0	21·0	...	...	...	4	12	15	NW	J. H. Apple, A.B.
[illegible]	Grampian Hills,	1,450	30·927	30·273	29·175	28·1	62·0		0·0	13	35·7	20·4	15·3	34·0	18, 19	6·0	7	...	...	3·00	8·0	8	3	16	12	NW	Nathan Moore.
[illegible]	Lock Haven,	560	...	...	...	32·2	62·0		6·0	13	...	...	...	...	...	...	...	...	...	2·33	7·0	9	8	11	12	W	Prof. John A. Robb.
[illegible]	Catawissa,	491	...	...	...	35·0	66·5		3·0	14	41·9	25·0	16·9	35·5	18	5·5	2, 3, 22	68·0	25·0	2·59	6·0	10	11	10	10	NW	Robert M. Graham.
[illegible]	Meadville— Allegheny College,	1,252	30·114	30·801	29·326	31·4	66·0		3·0	24	41·8	23·8	18·0	32·0	23	5·0	13	77·0	25·2	...	...	...	...	...	...	N, W	Prof. J. H. Montgomery.
Cumberland,	Carlisle— Dickinson College,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Charles F. Himes, Ph.D.
Cumberland,	Carlisle,	480	...	...	...	32·2	68·0		6·0	5	39·5	25·6	13·9	32·0	30	0·5	2	80·0	27·0	2·91	5·5	13	7	12	12	W	J. E. Pague.
Dauphin,	Harrisburg,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Zenos J. Gray, M.D.
Delaware,	Swarthmore— Swarthmore College,	190	30·072	30·543	29·620	33·1	69·5		6·0	6	41·9	25·3	16·6	28·5	31	8·6	17	72·0	25·2	5·41	..	10	12	8	11	NW	Prof. Susan J. Cunningham.
Elk,	Ridgway,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Joe Messinger.
Erie,	Erie,	681	30·110	30·560	29·140	27·0	67·4		3·0	24	36·5	20·2	16·3	38·9	19	5·5	5, 28	76·9	20·2	2·04	...	16	5	14	12	W	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·033	30·386	29·499	37·4	72·0		7·0	6	46·1	27·0	19·1	42·0	19	8·0	17	73·2	29·5	3·00	7·0	9	7	15	9	NW	Wm. Hunt.
Forest,	Tionesta,	1,058	...	...	...	28·4	68·0		5·0	13, 24	43·2	21·1	22·1	42·0	19	10·0	16	75·2	21·4	...	...	...	5	8	18	N	Robert L. Haslet.
Franklin,	Chambersburg— Wilson Female College,†	618	30·093	30·578	29·309	30·3	63·5		−5·0	6	40·1	23·1	17·0	38·0	19	7·0	5	81·5	24·7	1·72	..	9	...	...	...	...	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875	...	...	...	33·5	68·0		0·1	6	44·2	24·5	19·7	33·0	6	6·0	13	74·7	26·4	3·76	8·0	11	12	10	9	N, W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	33·7	65·0		7·0	13, 14	42·9	23·8	19·1	36·0	10	10·0	2	75·9	26·7	3·26	5·5	10	11	12	8	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	32·7	67·8		3·0	13	40·8	23·2	17·6	36·0	19	6·0	13	86·5	28·8	3·34	2·5	14	5	9	17	W	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750	...	...	...	29·4	63·0		0·0	13	40·4	19·4	21·0	37·0	19	10·0	13	82·6	24·2	1·01	11·5	7	9	4	18	NW	T. F. Heebner, M.D.
[illegible]	Lancaster— Franklin and Marshall College,	413	...	...	...	32·4	61·7		1·5	6	41·5	22·6	18·9	28·4	14	7·3	2	77·6	26·4	4·50	12·9	11	9	10	12	W	A. M. Schmidt, A.B.
[illegible]	New Castle,	932	...	...	...	33·6	69·0		0·0	6, 13	44·3	22·8	21·5	40·0	19	9·0	13	73·8	26·2	2·01	2·0	7	1	11	19	NW	Wm. T. Butz.
[illegible]	Lebanon,	480	30·102	30·562	29·429	34·4	67·5		0·1	13	41·2	23·9	17·3	34·3	31	8·1	13	73·1	24·6	4·08	7·5	15	13	8	10	NW, SW	George W. Hayes, C.E., Ph.G.
[illegible]	Drifton— Drifton Hospital,	1,655	...	...	...	26·9	59·0		−5·0	13	38·5	18·5	20·0	31·0	4, 19	8·0	27, 29	...	...	1·11	...	7	7	9	15	NW	H. D. Miller, M.D.
[illegible]	Williamsport,	525	...	...	...	31·9	60·0		4·0	13	38·0	22·6	15·4	26·0	8, 25	6·0	11	77·9	26·3	3·09	4·1	7	5	13	13	W	E. H. Baker.
[illegible]	Smethport,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
[illegible]	Greenville— Thiel College,	1,000	30·055	30·585	29·438	28·8	67·3		4·0	13	39·6	20·4	19·2	39·0	19	6·0	3	79·9	21·5	1·92	3·0	14	3	12	16	NW	Prof. S. H. Miller.
[illegible]	Stroudsburg,	430	...	...	...	29·7	63·0		[illegible]	13	39·6	20·3	19·3	36·0	19	7·0	11	76·5	21·0	3·62	13·5	10	13	8	10	NW	N. C. Miller, M.D.
[illegible]	Pottstown,	150	...	...	...	33·5	68·0		4·0	6	40·8	26·9	13·9	30·0	10	1·0	2	71·0	25·5	5·35	12·0	10	14	6	11	NW	Charles Moore, D.D.S.
[illegible]	Bethlehem,	360	...	...	...	32·2	61·0		5·0	13	39·3	23·7	15·6	29·0	19	8·0	2, 11, 26	69·0	23·0	3·84	...	7	11	8	12	NW	Lerch & Rice.
[illegible]	Shamokin,	733	...	...	...	31·7	64·0		[illegible]	13	43·4	22·3	21·1	36·0	12	10·0	5	85·4	26·0	3·02	1·0	9	9	13	9	NW	G. R. Hanley.
[illegible]	New Bloomfield,	400	...	...	...	30·8	64·0		1·0	6	40·9	22·2	18·7	31·0	19	9·0	2, 7	...	...	3·95	7·5	6	12	8	11	W	Frank Mortimer.
[illegible]	Philadelphia,	117	30·081	30·570	29·360	35·1	70·0		6·2	13	41·4	27·0	16·4	27·5	31	6·8	13	67·1	24·3	5·42	12·1	14	9	10	12	NW	Luther M. Dey, Sgt. Sig. Corps.
[illegible]	Blooming Grove,	800	...	...	...	28·0	59·0		1·5	13	...	...	...	...	...	...	...	...	...	...	...	8	...	...	...	N	John Grathwohl.
[illegible]	Coudersport,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	D. W. Butterworth.
[illegible]	Girardville,	1,030	30·127	30·505	29·452	30·5	59·0		1·0	13	37·0	21·1	15·9	26·0	19	6·0	7	...	...	4·35	19·0	10	9	11	11	NW	E. C. Wagner.
[illegible]	Somerset,	2,250	...	...	...	30·0	67·0		1·0	13	40·6	20·5	20·1	36·0	20	5·0	13	80·6	24·2	3·25	5·5	11	4	9	18	NW, SW	W. M. Schrock.
[illegible]	Eagles Mere,	2,060	...	...	...	30·2	51·0		−6·0	13	30·2	15·1	15·1	23·0	18	6·0	27	68·0	21·0	4·34	20·0	7	8	10	13	NW	E. S. Chase.
[illegible]	Bernice,	2,200	30·279	30·675	29·675	26·1	60·0		−5·5	14	34·7	15·7	19·0	32·0	25	3·0	2	78·8	20·0	1·61	19·0	19	7	9	15	NW	C. R. Claghorn.
[illegible]	Montrose,	1,060	...	...	...	26·3	58·0		−4·0	13	31·1	16·5	14·6	37·0	22	6·0	11	...	...	...	14·4	..	10	7	14	NW	A. H. Berlin.
[illegible]	Wellsboro,	1,327	30·076	30·408	29·313	27·6	56·0		−2·0	13	35·5	20·3	15·2	...	...	...	...	...	...	3·60	10·2	9	2	8	21	NW	H. D. Deming.
[illegible]	Franklin,	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
[illegible]	Scenery Hill,	1,750	...	...	...	34·0	66·0		6·0	13, 14	42·2	24·8	17·4	30·0	30	2·0	3	...	...	1·58	...	...	5	10	16	S	Jacob Gayman.
[illegible]	Washington,	1,175	...	...	...	30·9	68·7		0·0	13, 14	43·3	27·2	16·1	36·0	19	3·0	17	...	...	3·32	...	12	3	10	18	NW	Harrison Otis.
[illegible]	Columbus,	1,410	30·227	30·645	29·376	28·3	68·0		0·0	13	37·8	18·9	18·9	45·0	19	1·0	11	...	...	1·74	...	15	7	8	16	SW	Wm. Loveland.
[illegible]	Dyberry,	1,100	...	...	...	23·4	54·0		−5·0	18	32·6	14·1	18·5	45·0	19	5·0	11	...	...	4·01	18·7	15	8	5	18	NW	Theodore Day.
[illegible]	Greensburg,	1,075	...	...	...	34·9	70·0		7·0	13, 14	45·0	24·5	20·5	40·1	19	8·0	17	72·8	27·0	1·77	...	12	5	9	17	W	H. S. Brunot.
York,	York,	385	...	...	...	33·9	69·0		−2·5	6	42·7	24·9	17·8	31·5	6	6·0	2	71·7	26·0	3·78	9·5	16	12	8	11	NW	Mrs. L. H. Grenewald.

*Observations taken at 12, Noon. † Observations taken at 8 A. M. and 8 P. M.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PRECIPITATION FOR [M]ARCH, 1888.

Day	[illegible]	[illegible]	[illegible]	Washington	Pittsburgh	Columbus	Clarion	Uniontown	Indiana	Somerset	Grampian Hills	Emporium	Phillipsburg	Hollidaysburg	Altoona	Charlesville	State College	Huntingdon	McConnellsburg	Lock Haven	Williamsport	Chambersburg	New Bloomfield	Carlisle
1				·04	·07	·04	·08		·20											·04				
2				[illegible]	·15	·32	·30		·20			·40	·11	·18	·03	·06	·25	·03	·05	·11	·14			
3						·08		·25	·13	·23	·50				·05	·01		·10	·01					
4																								
5										·08						·13	·04	·03	·30				·20	
6						·01		·18							·02									
7									·01				·31											
8																								
9																								
10																								
11				[illegible]	·55	·47		·06	·52	·45	·72	·61	·34	·98	·17	1·31	·82	1·24	1·81	·33	1·00		1·20	
12				·04	·02	·04		·16							·27									
13	[illegible]			·04	·03	·03			·02	·20						·01	·02							
14	·01				·03	·01		·06		·03						·01								
15													·36											
16				·38	·33	·01		·44	·80	·20	·12			·07		·10	·10			·24				
17					·01										·07									
18													·04											
19																								
20	·10					·11	·08				·11	·10	·02	·03	·02		·02		·17	·04				
21	·22			·35	·25	·10	·25	·20	·42	·45	·51	·40	·02	·53	·45	·85	·77	·85	·47	·75	1·10		[illegible]	
22	·19			·08		·05																		
23	·01								·01				·02											
24					·03			·12								·01								
25	·04	·8			·09				·00	·05			·20			·18		·21	·15		·02			
26	·06	·26	·10	·39	·27	·25	·45		·25	·90	·42	·47	·14	·51	·34	·28	·33	·27	·51	·15	·44		[illegible]	
27	·26	·16			·12				·02				·04			·15	·02	·08	·08					
28	·1	·1	·25	·12	·32	·09	·02		·35	·53	·20	·24	·11	·25	·10	·10		·25	·15	·26	·04			
29	·11			1·00	·24	·13	·46	·84	·32	·13	·42	·66	·35		·23	·22	·48	·20	·16	·41	·35			
30																								
31																								
			2·01	3·32	2·51	1·74	1·70	3·00	3·34	3·25	3·00	2·88	2·06	2·55	1·75	3·42	2·85	3·26	3·76	2·33	3·09		[illegible]	

Day	Wysox	Eagles Mere	Bernice	Catawissa	Shamokin	Girardville	Lebanon	Lancaster	Drifton	Scranton	Kutztown	Pottstown	West Chester	Coatesville	Dyberry	Blooming Grove	Bethlehem	Quakertown	Swarthmore	Philadelphia	Stroudsburg
1	·12		·02	·05		·12	·01			1·00				·02							·30
2	·12		·07	·07	·08		·02	·05		·05			·03		·10			·02		·02	
3			·09				·01						·03	·02	·02		·04	·09		·05	
4			·01																		
5							·09	·50			·09	·22	·22	·32			·02	·04	·30	·15	
6			·01										·01		·01						
7			·05			·10							·01		·01						
8			·05												·07						
9																					
10																					
11	·45	1·35	·65	1·14	·96	1·07	1·40	1·58	·21	·55	·83	1·50	1·65	1·30	·30			1·14	1·38	1·25	·56
12			·50		·05				·65		·50	·80	1·05	1·31	1·50		1·44	·82	1·08	1·27	
13	·05	·70				·09	·01	·05	·42						·15						·05
14			·40								·16	·06	·05	·01	·05			·10		·02	·05
15																					
16			·01	·01	·4[illegible]		·05	·15				·12	·08	·16				·09	·10	·08	
17			·01																		
18																					
19																					
20	·04	·18	·11	·02	·10	·36	·31	·45		·14	·62	·20	·48	·46	·08			·24	·50	·50	·17
21	·47	·82	·51	·24	·38	1·27	·78	·45	1·20	·36	·34	·70	1·04	·96	·32		·88	·70	·95	·87	·70
22			·04				·01		·05				·05		·02			·01			
23																					
24																					
25	·25	·04	·06	·22		·51	·11	·24	·06		·03	·30	·16	·20					·19	·02	[illegible]
26	·26	·90	·38	·33	·68	·36	·87	·65	·52	·55	·63	·05	·83	·92	1·04		1·18	1·13	·30	·60	1·10
27	·31					·11	·05	·08			·45		·22	·07			·04	·10		·11	·30
28	·30	·35	·30	·06	·07		·06					·50	·12	·14	·07		·24	·03	·13	·07	
29			·36	·40	·32	·36	·30	·30		·36			·36	·30	·32			·34	·48	·41	·31
30																					
31																					
	[illegible]	4·34	3·63	2·50	3·02	4·35	4·08	4·50	3·11	3·01	3·65	5·35	6·39	6·28	4·01		3·84	4·94	5·41	5·42	3·62

T F T.

PENNSYLVANIA STATE WEATHER SERVICE BULLETIN.

REVIEW FOR APRIL, 1888.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 30, 1888.

TEMPERATURE.

The average temperature for April, 1888, deduced from the tri-daily observations was 46·5, which is normal. Found from the mean maximum and mean minimum, it was 47·2, which differs only seven-tenths from the normal. A deficiency of heat existed until the latter part of the month, when the extreme high temperatures of the 27th, 28th, 29th and 30th brought it up to the monthly average. Owing to the low temperatures of January, February and March, a deficiency for the year existed at the close of the month which made the season some ten days behind that of former years. The first week in the month was comparatively warm, but was followed by cold which continued until the 26th. The highest temperatures were recorded on the 29th and 30th, and averaged 88°·2, the extreme being 92° at York. This is probably the warmest April weather ever recorded in Pennsylvania. The lowest temperatures were Bethlehem, 12°; Coudersport, 15°; Lock Haven, 15°; Grampian Hills, 16°; Eagles Mere, 16°, and Bernice, 17°. Most of the low temperatures occurred on the 8th, 9th, 13th and 25th.

ATMOSPHERIC PRESSURE.

The barometer averaged high during the month, being ·15 above the mean, with a range of about one inch. The highest occurred on the 25th and 26th, and the lowest on the 2d.

PRECIPITATION.

The rainfall was quite evenly distributed, and averaged 2·52 inches for the State, which is a deficiency of nearly half an inch. Most of it fell during the middle of the month. The latter part of the month was quite dry. The heaviest rainfalls were on the 5th and 10th, and were attended by thunder storms, which were severe and general throughout the State on the 5th, several of the observers reporting damage by lightning. Snow fell at many

stations during the storms of the 14th and 16th, the greatest amounts being north and east of the Susquehanna River. The following are the largest totals for the month: Eagles Mere, 8·7 inches; Bernice, 7·3 inches; Dyberry, 6·5 inches; Wellsboro, 6·0 inches; Coudersport, 4·7 inches, and Montrose, 4·5 inches. Many of the Western stations had only "ground slightly covered" at any time during the month.

WIND AND WEATHER.

No violent wind storms of a general character passed over the State during April. The prevailing direction of wind was Northwest. The month was characterized by a large percentage of clear and fair days, and unusually low humidity. Frosts were numerous, but owing to the backwardness of the season they did but little damage. The warm weather at the close of the month gave vegetation a vigorous start.

Average number.—Rainy days, 8; clear days, 14; fair days, 10; cloudy days, 6.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Coudersport, 1st, 5th; Tionesta, 2d, 5th; Wellsboro, 2d, 5th; Lebanon, 5th; Uniontown, 5th; New Castle, 1st, 5th; Emporium, 1st, 2d, 5th; Quakertown, 5th; Charlesville, 5th, 10th, 30th; Catawissa, 5th, 10th, 30th; Erie, 1st, 2d, 5th, 10th; Rochester, 5th; York, 5th, 6th; Girardville, 5th, 30th; Shamokin, 5th, 6th, 30th; Kutztown, 5th; Johnstown, 5th; Scranton, 5th, 30th; Hollidaysburg, 5th; Lancaster, 5th; Bernice, 5th, 30th; West Chester, 5th; Washington, 2d, 5th; Somerset, 5th, 6th, 10th; Phillipsburg, 5th; Huntingdon, 5th; Swarthmore, 5th; Coatesville, 5th; Dyberry, 5th; Indiana, 5th, 10th; Montrose, 5th; Blooming Grove, 5th; Pittsburgh, 5th, 10th; Philadelphia, 6th; Carlisle, 5th, 6th; New Bloomfield, 5th, 6th, 30th; Clarion, 2d, 5th, 6th, 18th; Greenville, 1st, 5th; Grampian Hills, 2d, 5th, 30th; State College, 5th, 10th; Stroudsburg, 5th; Eagles Mere, 5th, 30th.

Hail.—Uniontown, 10th; New Castle, 5th; Emporium, 1st; Charlesville, 5th, 10th, 15th, 20th; Erie, 2d; Bernice, 12th; Somerset, 6th; Dyberry, 10th; Indiana, 10th; Greenville, 5th, 17th.

Frosts.—Charlesville, 4th, 9th, 17th, 19th, 25th, 26th; Uniontown, 1st, 9th, 24th, 28th; Emporium, 3d, 9th, 13th, 17th, 19th, 22d, 23d, 24th, 25th, 26th; Lebanon, 9th, 26th; Catawissa, 1st, 3d, 7th, 9th, 13th, 17th, 24th, 25th; York, 1st, 9th, 19th, 22d, 25th, 26th; Rochester, 3d, 4th, 8th, 19th, 26th; Johnstown, 1st, 4th, 9th, 12th, 13th, 14th, 15th, 17th, 25th, 26th, 27th; Hollidaysburg, 9th, 19th; Somerset, 13th; Erie, 3d, 4th, 8th, 9th, 13th, 15th, 17th, 23d, 25th; Indiana, 9th; Pittsburgh, 3d, 4th, 8th, 9th, 13th, 15th, 17th, 23d, 24th, 25th; Carlisle, 9th, 26th; Philadelphia, 1st, 2d, 3d, 4th, 8th, 9th, 12th, 13th, 17th, 19th, 21st, 23d, 24th, 25th; North Bloomfield, 25th, 26th; Clarion, 3d, 4th, 8th, 9th, 13th, 17th, 22d, 24th; Grampian Hills, 3d, 8th, 9th, 19th, 24th; Greenville, 3d, 4th, 8th, 9th, 13th, 15th, 23d, 24th, 25th; State College, 7th, 8th, 13th; Eagles Mere, 9th, 17th, 25th.

Auroras.—Catawissa, 11th; Kutztown, 2d; Bernice, 6th; Dyberry, 11th; Montrose, 6th, 11th; Greenville, 2d; Grampian Hills, 2d; State College, 2d; Stroudsburg, 2d, 11th; Eagles Mere, 3d, 11th.

Solar Halos.—Charlesville, 4th, 13th, 15th, 17th, 23d; York, 13th; Dyberry, 17th; Eagles Mere, 1st, 6th, 17th, 19th.

Lunar Halos.—Lebanon, 22d; New Castle 17th; Quakertown, 22d; Charlesville, 17th; Erie, 3d, 4th, 9th, 18th, 22d; Greenville, 22d; Hollidaysburg, 22d; Lancaster, 19th, 20th, 21st, 22d, 23d, 24th, 25th, 26th; Bernice, 18th; Somerset, 17th; Phillipsburg, 17th; Indiana, 17th, 23d; State College, 22d.

Lunar Coronæ.—Lebanon, 18th, 22d; Charlesville, 23d; Greenville, 21st, 22d; Eagles Mere, 22d.

Parhelia.—Dyberry, 17th, 19th.

T. F. T.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.

Displayman.	*Station.*
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.

West Chester.	Coatesville.	Dyberry.	Blooming Grove.	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.	Stroudsburg	Coudersport.
.	. .	·08	. .	. .	·02	. .	. .	·01	. .
·02	. .	. .	. .	. .	. .	. .	. .	. .	. .
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.	. .	. .	. .	. .	. .	. .	. .	. .	. .
·35	·33	1·00	. .	1·67	1·17	·34	·41	1·31	1·30
·16	·21	·38	1·60	. .	·65	·12	·09	·36	.
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.	. .	. .	. .	. .	. .	. .	. .	. .	. .
.	. .	. .	. .	. .	. .	. .	. .	. .	. .
92	·52	·42	·90	1·05	1·48	1·37	·61	1·22	. .
04	·03	·40	. .	. .	·08	·01	·03	. .	·50
05	·08	. .	. .	. .	·09	. .	. .	·01	.
.	. .	. .	. .	. .	.	. .	. .	.	·20
08	·10	·18	·20	. .	·08	. .	·04	·06	·20
.	. .	. .	. .	. .	. .	.	. .	. .	. .
61	·56	·15	. .	·47	·48	·54	·58	·23	·30
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48	2·02	2·98	2·80	3·32	4·23	2·64	2·10	3·36	3·00

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PRECIPITATION FOR APRIL, 1888.

Day	Meadville	Greenville	New Castle	Rochester	Washington	Pittsburgh	Columbus	Clarion	Uniontown	Indiana	Somerset	Johnstown	Grampian Hills	Emporium	Phillipsburg	Hollidaysburg	Altoona
1							·02							·04			
2		[illegible]				·01	·26	·09		·02	·03	·03	·05	·19			
3																	
4																	
5	1·42	·80	1·20	·04	·02	·07	·80	·49	·10	·30	·03	·60	·40	1·00		·84	·33
6				·25	·40	·18	·55	·95		·28	·95	·46	·46	·64	·07	·52	·53
7									·42								
8																	
9																	
10		·55	·36	·22		·17	·70	·55	·47	1·05	·17	1·18	·46	·57	·02	·50	·50
11			·50				·20	·08				·02		·17	[illegible]		[illegible]
12				·10		·15				·21	·13	·20	·14		·05	·12	·17
13																	
14				·07		·02	·03	·06		·30	·41	·22	·21	·16	·13	·05	[illegible]
15	[illegible]	·11		·02		·02	·02			·02	·11	·14					
16	·1	·05					·18	·12		·03		·02	·11		·26		·02
17																	
18	·10	·29	·25	·20		·12	·22	·35		·35		·15	·24		·14		
19	·14	·16	·23	·21		·09	·09		·18	·15		·05	·20	·02	·12		
20		·01			·35	·10	·05	·13	·08	·25	·23	·06		·12	·12	[illegible]	·14
21				·08	·14	·05			·07		·25	·05			·11		
22					·08	·03					·13	·05					
23						·01			·10		·10						
24																	
25																	
26																	
27																	
28																	
29																	
30		·21	·32			·02	·18			·02		·01			·03		
	[illegible]	·73	2·95	1·19	0·99	1·04	3·30	2·82	1·42	2·08	2·54	3·24	2·27	2·01	1·31	2·38	2·34

Day	Charlesville	[illegible]	Huntingdon	McConnellsburg	Lock Haven	New Bloomfield	Carlisle	York	Wysox	Eagles Mere	Bernice	Catawissa	Shamokin	Girardville	Lebanon	Lancaster	Montrose	Drifton	Scranton
1					·05				·25	·22	·10	·01			·01				·03
2					·02						·02				·01		·25		
3																			
4																			
5			[illegible]	·28	1·25	·50	·43	·40	·61	1·14	·80	1·50	·78	1·61	·42	·49	·51	1·45	1·00
6			[illegible]	·53	·34	1·00	·50	·06			·10		·44		·74	·23	·96		·02
7																			
8																			
9																			
10			·17	[illegible]	·20	1·00	·57	·44	·05	·72	·45	·45	·31	·82	1·15	·67		·65	·12
11					·03		·66				·12				·06		·20		·01
12			·17	·03			·02	·05			·05	·15	·05		·10	·03		·18	
13									·07										
14			·07	·18	·06	·02	·03	·14	·15	·31	·10	·11	·02	·06	·05	·07	·20	·12	·23
15				·09		·03			·10							·30			
16			[illegible]	·08	·25		·36	·02		·31	·51	·40	·26	·19	·47	·02	·16	·28	·30
17									·04										
18							·01			·06	·43	·02			·01		·19		·07
19					·10				·35	·61	·15	·25							
20			[illegible]	·13	·12	·20	·21	·05		·10	·16			·44	·10	·11	·09		·27
21																			
22				·04															
23				·04				·01								·01			
24																			
25																			
26																			
27																			
28																			
29																			
30									[illegible]		[illegible]	·02	·27	·17					
			2·16	2·54	2·51	2·75	2·70	1·17	1·91	3·47	3·03	2·01	2·13	3·29	3·12	[illegible]	3·25	2·68	2·05

Day	Kutztown	Pottstown	West Chester	Coatesville	Dyberry	Blooming Grove	Bethlehem	Quakertown	Swarthmore	Philadelphia	Stroudsburg	Coudersport
1					·08			·02			·01	
2												
3												
4												
5	·98	·80		·33	1·00		1·67	1·17	·14	·41	1·31	1·30
6	·41		[illegible]	·21	·38	1·60		·65	·12	·09	·36	
7												
8												
9												
10		1·20		·52	·42	·90	1·05	1·19	1·47	·61	1·22	
11	·05			·13	·40			·08	·01	·03		·50
12	·07	·12		·08				·09			·01	
13	·06											·20
14				·10	·18	·20		·08		·04	·06	·70
15	·10											
16	·25	·60	[illegible]	·56	·15		·47	·48	·54	·58	·23	·30
17												
18					·18	·10						·30
19												
20	·22	·15		·07	·17		·13	·18	·11	·16	·16	·20
21					·02							
22												
23				[illegible]					·15	·18		
24												
25												
26												
27												
28												
29												
30												
	2·16	2·87	[illegible]	[illegible]	2·08	2·80	3·32	4·23	2·64	2·10	3·36	3·00

T. F. T.

	Relative Humidity.	Dew Point.	PRECIPIT Total Inches.	Total Depth of Snow (inches)
Al	51·0	36·0	1·04	. .
Be	50·5	40·2	1·19	. .
Be	61·8	34·0	2·14	0·
Be	. .	. . .	. . .	. .
Be	. .	. . .	2·16	2·
Bl	9·3	34·5	2·34	. .
Bl	7·2	32·5	2·38	. .
Br	5·4	31·5	1·82	. .
Bu	4·9	34·7	4·23	2·
Bu	. .	. . .	. . .	. .
Ca	9·9	33·2	3·24	. .
Ca	9·4	34·2	2·91	. .
Ce	3·3	35·5	2·79	0·
Ce	. .	. . .	1·31	0·
Ch	4·9	32·8	2·48	0·
Ch	. .	. . .	2·02	1·
Cl	. .	. . .	. . .	. .
Cl	5·6	32·7	2·82	. .
Cl	. .	. . .	2·27	0·
Cl	0·0	39·0	2·51	. .
Co	4·3	36·0	2·91	. .
Cr	9·2	46·8	2·71	. .
Cu	4·8	41·2	2·79	. .
De	4·2	34·8	2·64	.
El	. .	. . .	. . .	. .
Er	6·7	32·0	2·70	. .
Fa	2·4	42·2	1·42	. .
Fo	1·2	34·2	. . .	. .
Fr	. .	. . .	. . .	. .
Fu	0·1	35·7	2·54	. .
Hu	5·5	36·8	2·66	. .
In	9·5	37·3	2·98	. .
La	0·3	36·5	2·05	1·
La	2·1	35·7	2·02	0·
La	2·3	37·2	2·95	. .
Le	3·5	36·0	3·12	2·
Lu	. .	. . .	2·68	. .
Ly	. .	. . .	. . .	. .
Mc	. .	. . .	. . .	. .
Me	1·5	35·4	2·73	. .
M	7·7	36·0	3·36	1·
M	·7	37·5	2·87	. .
N	·7	34·0	3·32	. .
N	·7	34·0	2·13	. .
Pe	·0	33·3	2·75	. .
Ph	·1	32·8	2·10	0·
Pi	.	. . .	2 80	3·
Po	·7	31·7	3·00	4·
Sc	.	. . .	3·29	3·
So	·9	35·7	2·54	3·
Su	·6	25·8	3·47	8·
Su	·5	32·7	3·03	7·
Su	.	. . .	3·25	4·
Ti	·1	36·4	2·49	6·
Ve	.	. . .	. . .	. .
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Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for April, 1888.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Total Depth of Snow (inches).	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction.	Observers.
Allegheny,	Pittsburgh,	847	30·119	30·570	29·550	50·5	[illegible]	29	25·5	8	61·6	38·9	22·7	38·1	1	8·5	20	61·0	36·0	1·04	...	14	9	11	10	N, W	Oscar D. Stewart, Sgt. Sig. Corps.
Beaver,	Rochester,	821	...	...	...	45·6	[illegible]	29	22·0	8, 13	60·7	34·1	26·6	45·0	26	12·0	14	80·5	40·2	1·19	...	9	9	13	8	W	Hon. Hartford P. Brown.
Bedford,	Charlesville,	1,500	...	...	...	47·3	[illegible]	29	20·0	25	60·1	33·8	26·3	48·0	26	10·0	20	61·8	34·0	2·14	0·5	10	17	7	6	N	Rev. A. Thos. G. Apple.
Berks,	Reading— Selwyn Hall School,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. George A. Ruddle.
Berks,	Kutztown— Keystone State Normal School,	1,500	...	...	...	44·8	[illegible]	30	27·0	8	53·7	38·6	15·1	36·4	30	3·8	11	...	...	2·16	2·5	8	...	...	...	...	Prof. J. H. Rohrbach.
Blair,	Altoona,	1,209	...	...	...	49·1	[illegible]	30	25·0	13	60·3	38·1	22·2	33·0	27	12·0	11	59·3	34·5	2·34	...	8	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	47·2	[illegible]	29	20·0	25	61·8	31·7	30·1	57·0	26	8·0	20	57·2	32·5	2·38	...	6	17	11	2	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	...	...	...	42·6	[illegible]	29, 30	23·0	13	56·2	33·3	22·9	42·5	27	7·0	10	65·4	31·5	1·82	...	9	11	11	8	NW	Charles Beecher.
Bucks,	Quakertown,	536	30·080	30·580	29·640	46·1	[illegible]	29	23·0	9	58·5	34·0	24·5	47·0	28	10·0	20	64·9	34·7	4·23	2·5	9	16	9	5	NW	J. L. Heacock.
Butler,	Butler,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
Cambria,	Johnstown,	1,184	30·107	30·420	29·630	46·5	[illegible]	29	21·0	25	62·0	32·6	29·4	51·0	27	15·0	20	59·9	33·2	3·24	...	15	16	8	6	NW	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	47·6	[illegible]	28, 29	20·0	25, 26	58·3	30·7	27·6	56·0	26	11·0	21	59·4	34·2	2·91	...	9	14	9	7	NW	T. B. Lloyd.
Centre,	State College— Agricultural Experiment Station,	1,191	30·154	30·597	29·588	46·9	[illegible]	29, 30	20·0	13	56·0	33·7	22·3	37·0	28	9·0	14	63·3	35·5	2·79	0·5	10	13	11	6	W	Prof. Wm. Frear.
Centre,	Philipsburg,	1,350	...	...	...	49·9	[illegible]	29	19·0	13, 14	57·6	32·0	25·6	47·0	28, 29	11·0	5, 10	...	...	1·31	0·5	11	17	5	8	SW	L. Ray Morgan.
Chester,	West Chester,	455	30·128	30·585	29·587	48·0	[illegible]	29, 30	28·0	8	58·5	37·8	20·7	32·5	27	9·5	11	54·9	32·8	2·48	0·5	10	16	9	5	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	47·3	[illegible]	29	24·0	9	61·0	35·6	25·4	51·5	28	12·0	10	...	...	2·02	1·0	9	16	11	3	W	W. T. Gordon.
Clarion,	Rimersburg,	1,500	...	...	...	47·6	[illegible]	28	25·0	12	54·3	40·4	13·9	2·4	26	3·0	18	...	...	...	...	...	6	18	6	NW	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	44·0	[illegible]	28	20·0	8	51·3	36·2	15·1	36·0	27	5·5	21	65·6	32·7	2·82	...	8	16	10	4	W	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	30·130	30·530	29·730	43·1	[illegible]	28	16·0	8	54·0	32·0	22·0	46·0	26	4·0	14	...	...	2·27	0·5	9	14	12	4	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	47·6	[illegible]	29	15·0	21	63·2	31·3	21·9	50·0	27	10·0	14	70·0	39·0	2·51	...	10	12	13	5	W	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	52·0	[illegible]	28, 29	26·0	9	59·9	36·7	23·2	45·0	27	7·0	20	54·3	36·0	2·91	...	9	14	12	4	W	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,252	30·148	30·506	29·691	56·6	[illegible]	28, 29	23·0	8, 13	56·6	32·7	23·9	43·0	28	8·0	20	69·2	46·8	2·71	...	5	...	...	...	W	Prof. J. H. Montgomery.
Cumberland,	Carlisle,	480	...	...	...	48·7	[illegible]	30	29·2	13	60·1	39·3	20·8	39·0	28	5·5	10	74·8	41·2	2·79	...	9	13	14	3	W	J. E. Pague.
Delaware,	Swarthmore— Swarthmore College,	190	30·123	30·548	29·660	48·4	[illegible]	29	27·8	9	59·3	37·9	21·4	38·5	28	10·5	11	54·2	34·8	2·64	...	7	14	13	3	N, W	Prof. Susan J. Cunningham.
Elk,	Ridgway,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Joe Messinger.
Erie,	Erie,	681	30·140	30·580	29·520	41·8	[illegible]	29	22·5	8	50·4	34·7	15·7	29·4	5	6·4	20	66·7	32·0	2·70	...	12	12	10	8	N, W	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	30·109	30·461	29·617	50·5	[illegible]	30	25·0	25	61·9	37·1	32·8	45·0	1	6·0	20	72·4	42·2	1·42	...	7	17	9	4	NW	Wm. Hunt.
Forest,	Tionesta,	1,058	...	...	...	43·0	[illegible]	28	18·0	13	60·3	32·3	28·0	31·0	27	5·0	20	71·2	34·2	...	...	...	8	14	8	NW	Robert L. Haslet.
Franklin,	Chambersburg— Wilson Female College,*	618	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875	...	...	...	48·7	[illegible]	29	23·0	25	62·5	35·6	26·9	48·0	27	12·0	6	65·1	35·7	2·54	...	10	17	10	3	W	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	47·9	[illegible]	29	21·0	25	61·1	32·9	28·2	55·0	26	10·0	10	65·5	36·8	2·66	...	7	12	13	5	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	47·3	[illegible]	28	19·5	13	58·9	34·1	24·8	40·0	28	10·5	14	63·5	37·3	2·98	...	12	10	10	10	NW	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750	...	...	...	45·7	[illegible]	29	23·0	9	56·7	34·2	22·5	50·5	27	9·5	10	70·3	30·5	2·05	1·0	...	...	...	...	...	T. F. Heebner, M.D.
Lancaster,	Lancaster— Franklin and Marshall College,	413	30·137	30·992	29·586	48·1	[illegible]	30	24·5	15	60·4	37·1	23·3	40·5	28	12·0	11	62·1	35·7	2·02	0·5	9	10	17	3	W	A. M. Schmidt, A.B.
Lawrence,	New Castle,	932	...	...	...	49·5	[illegible]	29	20·0	25	60·3	33·1	27·2	46·0	26	11·0	13	62·3	37·2	2·95	...	6	9	10	11	NW	Wm. T. Butz.
Lebanon,	Lebanon,	480	30·148	30·627	29·611	42·3	[illegible]	30	26·0	9	59·9	35·6	24·3	46·6	28	8·9	10	63·5	36·0	3·12	2·1	11	15	12	3	NW	George W. Hayes, C.E., Ph.G.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	42·5	[illegible]	29, 30	20·0	13	55·3	32·4	22·9	41·0	28	13·0	20	...	...	2·68	...	5	12	13	5	NW	H. D. Miller, M.D.
Lycoming,	Williamsport,	525	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. H. Baker.
McKean,	Smethport,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Armstrong & Brownell.
Mercer,	Greenville— Thiel College,	1,000	30·056	30·423	29·331	43·2	[illegible]	29	20·0	13	56·7	31·5	25·2	43·4	26	8·8	20	74·5	35·4	2·73	...	11	8	12	10	NW	Prof. S. H. Miller.
Monroe,	Stroudsburg,	430	...	...	...	45·9	[illegible]	29	23·0	9	59·6	33·3	26·3	50·0	28	13·0	15	67·7	36·0	3·36	1·5	8	13	7	10	NW	N. C. Miller, M.D.
Montgomery,	Pottstown,	150	...	...	...	49·7	[illegible]	30	24·0	9	60·8	38·8	22·0	40·0	28	10·0	10	67·7	37·5	2·87	...	5	19	7	5	W, NW	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	30·081	30·496	29·590	48·8	[illegible]	30	12·0	18	58·8	35·4	23·4	47·0	28	3·0	23	57·7	34·0	3·32	...	4	14	9	7	NW	Lerch & Rice.
Northumberland,	Shamokin,	733	...	...	...	47·0	[illegible]	30	21·0	10	60·0	33·3	26·7	48·0	27	14·0	21	61·7	34·0	2·13	...	7	12	12	6	NW	G. R. Hanley.
Perry,	New Bloomfield,	400	...	...	...	46·4	[illegible]	29, 30	23·0	9	59·4	32·7	26·7	51·0	28	10·0	10	61·0	33·3	2·75	...	6	21	7	3	W	Frank Mortimer.
Philadelphia,	Philadelphia,	117	30·127	30·590	29·570	50·7	[illegible]	30	31·0	13	60·3	41·8	18·5	33·6	28	8·0	11, 20	53·1	32·8	2·10	0·5	8	14	10	6	NW	Luther M. Dey, Sgt. Sig. Corps.
Pike,	Blooming Grove,	800	...	...	...	43·8	[illegible]	29	24·0	8	53·8	37·6	16·2	32·0	9	2·0	20	...	...	2·80	3·0	4	13	10	7	W	John Grathwohl.
Potter,	Coudersport,†	...	...	...	...	43·0	[illegible]	30	15·0	13	52·9	28·0	24·9	45·0	28	8·0	15	64·7	31·7	3·00	4·7	7	...	...	6	NW	H. W. Butterworth.
Schuylkill,	Girardville,	1,030	30·015	30·718	29·733	46·3	[illegible]	30	25·0	9, 24	59·0	35·1	23·9	40·0	27	9·0	10	...	...	3·29	3·5	6	17	7	6	NW	E. C. Wagner.
Somerset,	Somerset,	2,250	...	...	...	43·4	[illegible]	28	18·0	13	59·0	31·0	28·0	48·0	27	14·5	21	74·9	35·7	2·54	3·7	11	13	11	6	NW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	...	...	...	41·6	[illegible]	29, 30	16·0	9, 13	47·8	27·9	19·9	36·0	27	8·0	14	53·0	25·8	3·47	8·7	8	13	10	7	NW	E. S. Chase.
Sullivan,	Bernice,	2,200	...	...	...	41·0	[illegible]	30	17·0	9	50·9	29·6	21·3	42·0	26	8·0	10	70·5	32·7	3·03	7·3	13	10	11	7	NW	C. R. Claghorn.
Susquehanna,	Montrose,	1,060	...	...	...	46·1	[illegible]	30	18·0	8	50·9	34·1	16·8	32·0	26	7·0	2, 4	...	...	3·25	4·5	8	13	11	6	NW	A. H. Berlin.
Tioga,	Wellsboro,	1,327	30·097	30·461	29·517	42·1	[illegible]	29	24·0	8	53·1	34·0	19·1	42·1	29	3·3	10	74·1	36·4	2·49	6·0	10	11	9	10	NW	H. D. Deming.
Venango,	Franklin,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. N. P. Kinsley.
Washington,	Scenery Hill,	1,750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Jacob Gayman.
Washington,	Washington,	1,175	...	...	...	50·6	[illegible]	28, 29	24·0	13, 25	60·2	36·9	23·3	41·7	26	8·5	18	...	...	0·99	...	5	12	12	6	NW	Harrison Otis.
Warren,	Columbus,	1,410	...	...	...	42·0	[illegible]	29	18·0	13, 25	54·7	29·1	25·6	50·0	26	2·0	14	...	...	3·30	...	13	14	7	9	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	40·3	[illegible]	29, 30	17·0	9	51·1	29·0	22·1	50·0	27	3·0	10	...	...	2·98	6·5	10	10	14	6	NW	Theodore Day.
Westmoreland,	Greensburg,	1,075	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H. S. Brunot.
York,	York,	385	...	...	...	51·9	[illegible]	30	22·5	1	61·7	36·3	25·4	42·5	27, 28	11·5	3	59·3	37·0	1·17	...	8	14	12	1	NW	Mrs. L. H. Grenewald.

Observations taken at 8 A. M. and 8 P. M. † From 3d to 30th.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW.

FOR MAY, 1888.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1888.

TEMPERATURE.

The mean temperature of May, 1888, 57°·6, is about 3° less than the May average. This departure, together with the deficiency that existed at the beginning of the month, and the unusual number of rainy and cloudy days and cold nights, has increased the lateness of the season, and the growth of vegetation is correspondingly backward.

The lowest reported temperatures were Coudersport, 23°·5; Drifton, 24°; Dyberry, 24°, and Phillipsburg, 24°. The highest were Phillipsburg, 91°; Johnstown, 90°; Coatesville, 89°; York, 87°·5; Kutztown, 87°·3; Altoona and Pottstown, 87°. The cold periods of the month were on the 3d and 17th, and the warmest on the 28th and 29th. A killing frost occurred on the 17th, which was general throughout the State. Considerable damage was done by it to fruit and tender vegetables.

ATMOSPHERIC PRESSURE.

The barometer was normal and ranged from 30·380 to 29·590 at Erie. The highest pressures occurred on the 6th, 7th, 8th and 20th; and the lowest on the 1st and 12th.

PRECIPITATION.

Rains were of almost daily occurrence, the 6th, 20th, 21st and 22d being the exceptions. The total average, 4·24 inches, gives an excess of about 1·10 inches. The central part of the State received the greater portion. Huntingdon reports 8·41 inches; Girardville, 7·08 inches; Drifton, 5·69 inches; Chambersburg, 5·55 inches, and Carlisle, 5·14 inches; while Erie had but 2·26 inches; Wysox, 2·31 inches; Bethlehem, 2·33 inches, and Meadville, 2·56 inches. The heavy rains occurred on the 9th, 18th and 28th. The latter, in many places, was attended by severe hail storms. Several stations report a light snowfall on the 15th.

WIND AND WEATHER.

No general and severe storms passed over the State during the month. Several sections were visited on the 28th by a tornado, which did a large amount of damage. The following are extracts from the reports of observers:

Rochester, 1.30 P. M.—Warning was given of the approach of a severe storm by loud thunder. The wind increased in velocity until fences, house

roofs, and trees were carried away. The Baptist Church was almost demolished and the Presbyterian Church badly damaged.

Huntingdon, 3 P. M.—Severe hail storm. Hail the size of hens' eggs fell plentifully, breaking windows and injuring fruit.

Emporium, 3.35 P. M.—One of the most terrific storms for years. Cameron Iron Works demolished. Trees from six to eight inches in diameter snapped off. Much damage to forest trees.

New Castle, 1.30 P. M.—Worst storm for twelve years. Came from southwest. Rain poured in torrents. High wind. Country roads obstructed by fallen trees. Houses and barns blown to pieces. Crops badly damaged.

Oil City, 2.30 P. M.—Most disastrous tornado. A large number of persons injured. At Clintonville Presbyterian Church demolished. At Clarion several buildings blown down.

Chambersburg, 4 P. M.—Storm of wind, rain and hail. Thousands of windows broken and buildings injured. For a short time hail stones from five to nine inches in circumference fell.

Lititz, 7.30 P. M.—Terrible hail storm from northwest. Hail stones ranged in size from a marble to four ounces. Thousands of windows broken. Damage to growing crops very great.

Several other stations report hail storms, and thunder storms on the 28th, with damage by lightning.

Average number.—Rainy days, 16; clear days, 4; fair days, 11; cloudy days, 16.

Prevailing direction of wind, west.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Pittsburgh, 4th, 8th, 9th, 12th, 25th, 28th, 31st; Rochester, 12th, 25th, 27th, 28th; Charlesville, 4th, 9th, 10th, 12th, 18th, 28th; Reading, 9th, 28th, 29th; Kutztown, 12th, 14th, 28th, 29th; Hollidaysburg, 4th, 18th, 22d, 28th; Quakertown, 12th, 14th, 28th, 29th; Johnstown, 4th; Emporium, 4th, 9th, 12th, 28th, 29th; State College, 4th, 5th, 9th, 28th; Phillipsburg, 22d, 28th; West Chester 29th; Coatesville, 5th, 12th, 28th, 29th; Rimersburg, 4th, 9th, 12th, 18th, 27th; Grampian Hills, 4th, 12th, 18th; Catawissa, 10th, 18th, 28th; Meadville, 4th; Carlisle, 5th, 9th, 12th, 28th, 29th, 30th; Swarthmore, 9th, 12th, 14th, 28th, 29th, 30th; Uniontown, 4th, 8th, 9th, 26th, 28th; Chambersburg, 28th; McConnellsburg, 12th; Huntingdon, 4th, 9th, 10th, 12th, 28th; Indiana, 18th; Scranton, 14th; Lancaster, 4th, 5th, 9th, 12th, 28th, 29th; New Castle, 12th, 28th, 31st; Lebanon, 9th, 12th, 28th, 31st; Greenville, 28th; Pottstown, 28th; Bethlehem, 12th, 14th, 28th, 29th; Shamokin, 18th; New Bloomfield, 12th, 28th, 30th; Coudersport, 19th; Girardville, 28th; Somerset, 4th, 9th, 12th, 18th, 28th; Eagles Mere, 12th, 28th, 30th; Bernice, 28th, 29th; Montrose, 28th, 29th; Wellsboro, 9th, 10th, 28th, 29th, 31st; Franklin, 4th, 9th, 27th, 28th, 30th; Columbus, 4th, 9th, 28th, 31st; Dyberry, 1st, 14th, 28th, 29th.

Hail.—Rochester, 25th; Hollidaysburg, 9th; Wysox, 15th; Coatesville, 5th, 17th, 29th; Rimersburg, 9th, 12th; Carlisle, 12th; Uniontown, 12th, 28th; Chambersburg, 28th; McConnellsburg, 17th; Huntingdon, 17th, 21st, 28th;

Indiana, 28th; Scranton, 28th; Smethport, 3d; Greenville, 28th; Montrose, 16th; Wellsboro, 15th; Dyberry, 15th.

Tornadoes.—Rochester, 28th; Emporium, 28th; Phillipsburg, 28th; Rimersburg, 28th; Smethport, 28th; Shamokin, 28th; Coudersport, 28th; Franklin, 28th.

Frosts.—Pittsburgh, 17th, 20th; Rochester, 17th, 20th; Charlesville, 3d, 17th, 21st; Kutztown, 17th; Wysox, 3d, 6th, 16th, 17th, 20th, 21st; Quakertown, 3d, 17th; Johnstown, 17th; Emporium, 17th, 20th, 21st; State College, 17th; West Chester, 17th, 21st; Coatesville, 3d, 21st; Rimersburg, 17th, 20th; Grampian Hills, 17th, 20th, 21st; Lock Haven, 17th, 20th, 21st; Catawissa, 3d, 17th, 21st; Carlisle, 17th; Erie, 20th; Uniontown, 17th; Tionesta, 13th, 17th, 21st; Chambersburg, 4th, 5th, 6th; Huntingdon, 2d, 3d; Indiana, 17th; New Castle, 17th, 18th; Lebanon, 3d; Greenville, 17th, 20th, 21st; Pottstown, 3d; Bethlehem, 17th; Shamokin, 21st; New Bloomfield, 17th, 21st; Philadelphia, 2d, 17th; Coudersport, 17th, 21st; Girardville, 22d; Somerset, 17th; Eagles Mere, 17th; Bernice, 3d; Montrose, 17th; Wellsboro, 2d, 3d, 5th, 6th, 7th, 14th, 15th, 16th, 17th; Franklin, 17th; Columbus, 3d, 6th, 13th, 17th, 20th, 21st; Dyberry, 15th.

Auroras.—State College, 20th; Coatesville, 20th; Catawissa, 20th, Scranton, 20th; Greenville, 7th, 20th; Stroudsburg, 20th; Girardville, 2d; Somerset, 20th; Eagles Mere, 20th; Wellsboro, 20th; Franklin, 20th.

Solar Halos.—Charlesville, 9th, 10th, 20th, 21st, 22d, 28th; Somerset, 20th; Eagles Mere, 22d, 23d; Wellsboro, 23d; Franklin, 10th, 12th; Dyberry, 23d.

Lunar Halos.—Pittsburgh, 22d, 23d; Rochester, 22d; Charlesville, 19th, 21st, 22d; Kutztown, 19th; Altoona, 19th; Wysox, 22d; Quakertown, 19th, 21st, 22d; State College, 21st, 22d; West Chester, 17th, 19th, 21st, 22d; Grampian Hills, 22d; Catawissa, 17th, 20th; Carlisle, 19th, 20th, 21st, 22d; Swarthmore, 20th, 21st, 22d; Chambersburg, 17th; Indiana, 19th, 21st, 22d; Scranton, 22d; Lancaster, 16th, 17th, 19th, 21st; New Castle, 25th; Lebanon, 19th, 22d; Smethport, 22d; Stroudsburg, 19th, 22d; Pottstown, 21st; Shamokin, 17th, 19th; New Bloomfield, 19th, 21st; Philadelphia, 21st, 22d; Girardville, 17th; Somerset, 19th, 21st, 22d; Eagles Mere, 17th, 22d; Wellsboro, 23d; Franklin, 22d; Dyberry, 22d; Honesdale, 19th, 21st.

Lunar Coronæ.—Charlesville, 20th; Huntingdon, 20th, 21st, 22d; Lebanon, 15th, 17th, 19th, 22d; Smethport, 19th; Stroudsburg, 17th, 21st; Eagles Mere, 22d; Dyberry, 14th.

T. F. T.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office, ...	Philadelphia.
Wanamaker & Brown, ...	"
Pennsylvania Railroad Company, ...	"
Continental Brewing Company, ...	"
Samuel Simpson, ...	"
B. T. Babbitt, ...	"

Displayman.	*Station.*
Western Meat Company,	Philadelphia.
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.

		Date.	Relative Humidity.	Dew Point.
All	8	23	67·7	49·
Bea	0	1	80·0	51·
Bec	0	24	76·3	50·
Ber	.	. . .	82·0	52·
Ber	7	15	. . .	. .
Bla	0	24	59·8	46·
Bla	0	24	80·8	52·
Bra	2	26	74·3	49·
Bu	7	11	80·0	52·
Bu	·	.	. . .	. .
Ca	0	24	73·2	47·
Ca	0	25	66·1	49·
Ce	0	11	73·9	49·
Ce	0	1	. . .	. .
Ch	0	18, 24	. . .	. .
Ch	0	11	. . .	. .
Cla	0	26	. . .	. .
Cla	5	26	74·8	48·
Cle	0	25	. . .	. .
Cli	0	24	. . .	. .
Co	0	1	77·0	54·
Cr	0	19	71·8	53·
Cu	0	24	87·0	57·
De	7	24	75·0	50·
El	·	. . .	. . .	. .
Er	0	18, 19	67·4	43·
Fa	0	23	70·5	54·
Fo	0	17	73·6	45·
Fr	0	24	82·3	52·
Fu	0	11	76·5	51·
H	8	24	76·1	50·
In	8	24	75·8	50·
La	0	26	76·7	50·
La	9	11	79·9	53·
La	0	8	72·0	50·
Le	0	18	79·9	52·
Lu	0	8	. . .	. .
Ly	·	. . .	. . .	. .
M	0	25	78·0	46·
M	1	18	73·1	37·
M	0	30	78·8	49·
M	0	18	77·0	52·
N	0	26	72·0	50·
N	0	25	71·8	49·
Pe	0	18	. . .	. .
Pl	0	31	70·4	50·
Pi	·	. . .	. . .	. .
P	0	19	72·4	46·
S	0	18	. . .	. .
S	0	25	83·8	47·
S	0	18	72·9	43·
S	0	26	75·8	45·
S	0	18 ·	. . .	. .
T	2	16	70·3	48·
V	0	8	72·0	48·
W	0	9	. .	. .
W	·	. . .	. . .	. .
W	0	1	. . .	. .
W	0	28	. . .	. .
W	0	8	. . .	. .
W	·	. . .	. . .	. .
Y	0	18	75·3	52·

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Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1888.

Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Maximum. Highest.	Maximum. Date.	Minimum. Lowest.	Minimum. Date.	Mean of Maximum.	Mean of Minimum.	Daily Range. Mean.	Daily Range. Greatest.	Daily Range. Date.	Daily Range. Least.	Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction.	Observers.
Pittsburgh,	847	29.938	30.310	29.640	61.4	85.2	28	37.2	17	71.2	52.5	18.7	31.7	3	9.8	23	67.7	49.8	4.13	18	2	19	10	. . .	Oscar D. Stewart, Sgt. Sig. Corps.
Rochester,	821	. . .	. . .	. . .	57.1	85.0	28	31.0	17	71.8	48.0	23.8	38.0	3, 4	6.0	1	80.0	51.0	3.32	12	7	16	8	W	Hartford P. Brown, Jr.
Charlesville,	1,300	. . .	. . .	. . .	[illegible]	86.0	28	28.0	17	67.6	46.6	21.0	37.5	6	5.0	24	76.3	50.0	4.83	20	7	8	16	N, W	Rev. A. Thos. G. Apple.
Reading— Selwyn Hall School,	. . .	. . .	. . .	. . .	[illegible]	82.0	29	32.0	3	66.0	50.4	15.6	. . .	. . .	. . .	. . .	82.0	52.6	3.83	15	5	8	18	W	Prof. George A. Riddle.
Kutztown— Keystone State Normal School,	540	. . .	. . .	. . .	[illegible]	87.3	29	47.8	3	63.9	52.5	11.4	27.1	29	1.7	15	. . .	. . .	3.11	15	3	7	19	. . .	Prof. J. H. Rohrbach.
Altoona,	1,181	30.190	30.460	[illegible]	[illegible]	87.0	29	35.0	17	71.2	50.0	21.2	37.0	2	10.0	24	59.8	46.4	4.08	15	. . .	. . .	. . .	. . .	Dr. Charles B. Dudley.
Hollidaysburg,	947	. . .	. . .	. . .	57.4	86.0	28	27.0	17	70.1	45.3	24.8	41.0	7	9.0	24	80.8	52.1	6.94	15	11	6	14	W	Prof. J. A. Stewart.
Wysox,	718	. . .	. . .	. . .	57.4	81.0	10, 27	27.5	3	67.2	46.9	20.3	36.5	6	9.2	26	74.3	49.3	2.31	15	5	7	19	NW	Charles Beecher.
Quakertown,	536	29.990	30.320	29.760	57.1	84.7	29	29.0	3	70.6	47.6	23.0	32.0	6	5.7	11	80.0	52.2	3.02	20	4	9	18	NW	J. L. Heacock.
Butler,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	J. E. Forsythe.
Johnstown,	1,184	29.865	30.160	29.600	[illegible]	90.0	28	30.0	17	71.1	48.4	22.7	41.0	7	8.0	24	73.2	47.5	4.74	18	10	15	6	. . .	E. C. Lorentz.
Emporium,	1,030	. . .	. . .	. . .	[illegible]	86.0	28	27.0	17	69.1	45.7	23.4	38.0	6	8.0	25	66.1	49.0	4.63	18	7	10	14	NW	F. B. Lloyd.
State College— Agricultural Experiment Station,	1,191	29.982	30.325	29.607	[illegible]	82.0	28	30.5	3	65.2	46.6	18.6	32.5	6	7.0	11	73.9	49.8	6.26	17	8	8	15	E	Prof. Wm. Frear.
Philipsburg,	1,350	. . .	. . .	. . .	[illegible]	91.0	30	24.0	17	71.1	45.1	26.0	42.0	17	7.0	1	. . .	. . .	4.96	19	6	17	8	SW	L. Ray Morgan.
West Chester,	455	29.998	30.271	29.752	[illegible]	86.0	29	36.0	3	67.1	51.7	15.4	28.0	29	5.0	18, 24	. . .	. . .	4.11	21	11	6	14	N.W, E	Jesse C. Green, D.D.S.
Coatesville,	380	. . .	. . .	. . .	[illegible]	89.0	29	29.0	3	69.1	49.7	19.4	35.5	3	6.0	11	. . .	. . .	2.89	20	6	9	16	E	W. T. Gordon.
Rimersburg,	1,500	. . .	. . .	. . .	[illegible]	85.0	28	36.0	14, 15	65.3	52.4	12.9	26.0	21	1.0	26	. . .	. . .	. . .	12	7	13	11	W	Rev. W. W. Deatrick, A.M.
Clarion— State Normal School,	1,530	. . .	. . .	. . .	[illegible]	81.5	28	36.5	15	64.0	50.3	13.7	24.0	21	2.5	26	74.8	48.2	3.46	11	3	17	11	E	C. M. Thomas, B.S.
Grampian Hills,	1,450	. . .	. . .	. . .	[illegible]	85.0	28	28.0	17	66.7	46.1	20.6	32.0	6, 13	4.0	25	. . .	. . .	4.58	13	7	11	13	E	Nathan Moore.
Lock Haven,	560	. . .	. . .	. . .	[illegible]	85.0	28	28.0	4	68.0	47.6	20.4	41.0	4	7.0	24	. . .	. . .	3.87	17	10	9	12	W	Prof. John A. Robb.
Catawissa,	491	. . .	. . .	. . .	[illegible]	84.5	29	31.0	3	69.0	51.1	17.9	36.0	21	7.0	1	77.0	54.8	5.20	15	1	11	16	S	Robert M. Graham.
Meadville— Allegheny College,	1,050	29.969	30.229	29.664	[illegible]	80.0	23, 28	33.0	17	70.0	50.0	20.0	39.0	23	10.0	19	71.8	53.0	2.56	8	. . .	. . .	. . .	. . .	Prof. J. H. Montgomery.
Carlisle,	480	. . .	. . .	. . .	[illegible]	86.5	29	40.5	2	68.1	54.3	13.8	28.5	3	3.0	24	87.0	57.0	5.14	19	6	7	18	W	J. E. Pague.
Swarthmore— Swarthmore College,	190	29.996	30.250	29.775	[illegible]	[illegible]	29	34.0	3	67.3	50.9	17.0	28.1	6	5.7	21	75.0	50.8	3.02	14	5	11	15	E	Prof. Susan J. Cunningham.
Ridgway,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Joe Messinger.
Erie,	681	29.970	30.380	29.590	[illegible]	81.0	4	36.0	2	62.9	47.7	15.2	30.0	4	6.0	18, 19	67.4	43.2	2.26	14	3	20	8	. . .	Peter Wood, Sgt. Sig. Corps.
Uniontown,	1,000	29.942	30.225	29.715	[illegible]	82.0	27	32.0	17	70.8	50.9	19.9	40.0	3	7.0	23	70.5	54.8	4.72	11	12	15	4	W	Wm. Hunt.
Tionesta,	1,058	. . .	. . .	. . .	[illegible]	83.0	28	29.0	16	71.5	47.3	24.2	35.0	13	5.0	17	73.6	45.2	. . .	. . .	[illegible]	[illegible]	22	. . .	Robert L. Haslet.
Chambersburg— Wilson Female College,*	618	29.984	30.226	29.741	[illegible]	86.0	29, 30	30.0	3, 17	70.8	48.1	21.7	42.5	6	[illegible]	24	82.3	52.6	5.55	15	12	7	12	. . .	Miss Mary A. Ricker.
McConnellsburg,	875	. . .	. . .	. . .	[illegible]	86.0	29	30.0	17	71.0	48.9	22.1	39.0	6	6.0	11	76.5	51.2	4.70	17	5	16	10	W	Thomas F. Sloan.
Huntingdon— The Normal College,	650	. . .	. . .	. . .	[illegible]	85.0	28	22.0	6	70.0	45.5	24.5	54.0	6	7.8	24	76.1	50.2	8.41	14	4	5	22	W	Prof. W. J. Swigart.
Indiana— State Normal School,	1,350	. . .	. . .	. . .	[illegible]	85.0	28	27.0	17	68.8	46.4	22.4	36.0	17	9.8	24	75.8	50.0	5.30	17	7	10	14	SW	Prof. Albert E. Maltby.
Scranton,	750	. . .	. . .	. . .	[illegible]	83.0	29	30.0	3	68.8	49.7	19.1	38.0	21	8.5	26	76.7	50.1	3.13	19	5	13	11	NW	T. F. Heebner, M.D.
Lancaster— Franklin and Marshall College,	413	29.992	30.284	[illegible]	[illegible]	86.1	29	31.5	3	68.4	50.0	18.4	30.0	3	5.0	11	79.9	53.3	3.30	20	5	9	17	E	A. M. Schmidt, A.B.
New Castle,	932	. . .	. . .	. . .	[illegible]	85.0	28	27.0	17	71.0	46.6	24.4	40.0	6	[illegible]	8	72.0	50.7	2.73	11	3	14	14	E	Wm. T. Butz.
Lebanon,	480	30.032	30.384	[illegible]	[illegible]	85.7	29	30.2	3	67.8	49.1	18.7	35.6	7	[illegible]	18	79.0	[illegible]	5.08	22	7	9	15	NE	George W. Hayes, C.E., Ph.G.
Drifton— Drifton Hospital,	1,655	. . .	. . .	. . .	[illegible]	[illegible]	29	24.0	16	67.4	46.3	21.1	39.0	21	[illegible]	8	. . .	. . .	5.69	13	8	7	16	. . .	H. D. Miller, M.D.
Williamsport,	525	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	E. H. Baker.
Smethport,	. . .	. . .	. . .	. . .	4.5	79.0	9	27.0	17	62.4	44.1	18.3	39.0	4	[illegible]	25	78.0	46.8	. . .	. . .	1	12	16	W	Armstrong & Brownell.
Greenville— Thiel College,	1,000	29.883	30.167	[illegible]	[illegible]	[illegible]	28	30.0	20	68.6	47.9	20.7	41.9	21	12.1	18	73.1	47.6	2.63	14	1	15	15	W	Prof. S. H. Miller.
Stroudsburg,	430	. . .	. . .	. . .	[illegible]	[illegible]	29	28.0	3	68.4	47.0	20.8	41.0	21	[illegible]	30	78.8	49.4	5.13	15	10	2	19	E	N. C. Miller, M.D.
Pottstown,	150	. . .	. . .	. . .	[illegible]	87.0	29	35.0	3	68.0	53.3	14.7	30.0	21	[illegible]	18	77.0	52.4	4.25	14	12	3	16	W	Charles Moore, D.D.S.
Bethlehem,	360	29.968	30.235	[illegible]	[illegible]	86.0	29	32.0	3	69.6	48.5	21.1	38.0	19	[illegible]	26	72.0	50.3	2.33	15	9	7	15	W	Lerch & Rice.
Shamokin,	733	. . .	. . .	. . .	[illegible]	[illegible]	29	26.0	3	67.7	47.0	20.1	38.0	21	[illegible]	25	71.8	49.0	6.11	19	5	11	15	W	G. R. Hanley.
New Bloomfield,	400	. . .	. . .	. . .	[illegible]	[illegible]	29	29.0	17	67.6	47.2	20.4	38.0	3, 6	[illegible]	18	. . .	. . .	6.55	16	4	6	21	E	Frank Mortimer.
Philadelphia,	117	30.010	30.300	[illegible]	[illegible]	[illegible]	29	42.5	2, 17	69.0	53.5	15.5	28.8	29	[illegible]	31	70.4	50.0	3.46	19	2	11	18	W	Luther M. Dey, Sgt. Sig. Corps.
Blooming Grove,	800	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	John Grathwohl.
Coudersport,	. . .	. . .	. . .	. . .	[illegible]	[illegible]	28	23.5	17	63.1	40.1	23.0	41.0	6	11.0	19	72.4	46.2	3.80	11	10	3	18	W	D. W. Butterworth.
Girardville,	1,000	30.026	30.293	[illegible]	[illegible]	[illegible]	29	31.0	3	68.8	48.0	20.8	36.0	22	5.0	18	. . .	. . .	7.08	17	11	9	11	W	E. C. Wagner.
Somerset,	2,250	. . .	. . .	. . .	[illegible]	83.0	28	28.0	3	67.6	44.8	22.8	47.5	3	[illegible]	25	83.8	47.0	5.85	18	8	9	14	SW	W. M. Schrock.
Eagles Mere,	2,060	. . .	. . .	. . .	[illegible]	76.0	29	29.0	17	59.1	43.8	15.3	26.0	6	[illegible]	18	72.9	43.2	3.70	15	2	12	17	. . .	E. S. Chase.
Bernice,	2,000	30.179	30.472	29.907	[illegible]	77.0	10, 29	24.0	3	63.0	42.6	20.4	48.0	6	[illegible]	26	75.8	45.2	2.55	17	5	14	12	SW	C. R. Claghorn.
Montrose,	1,656	. . .	. . .	. . .	[illegible]	81.0	27	31.0	17	64.1	47.6	16.5	27.0	27	[illegible]	18	. . .	. . .	3.03	15	6	11	14	. . .	A. H. Berlin.
Wellsboro,	1,327	29.977	30.363	[illegible]	[illegible]	80.0	27	30.0	21	62.2	46.9	15.3	69.2	29	[illegible]	16	70.3	48.0	3.16	14	8	11	12	. . .	H. D. Deming.
Franklin,	. . .	. . .	. . .	. . .	[illegible]	81.0	28	36.0	17	65.4	50.5	14.9	28.0	21	[illegible]	8	72.0	48.5	4.09	14	4	16	11	W	Prof. N. P. Kinsley.
Scenery Hill,	1,750	. . .	. . .	. . .	[illegible]	81.0	28	34.0	2	65.7	49.5	16.2	35.5	3	7.0	9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Jacob Gayman.
Washington,	1,175	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	Harrison Otis.
Columbus,	1,410	30.064	30.366	[illegible]	[illegible]	82.0	28	26.0	17, 21	67.4	43.2	24.2	54.0	21	[illegible]	1	. . .	. . .	2.80	18	8	11	12	W	Wm. Loveland.
Dyberry,	1,100	. . .	. . .	. . .	[illegible]	78.0	29, 30	24.0	3	63.8	32.9	30.9	39.0	6	7.0	28	. . .	. . .	3.86	14	3	11	17	W	Theodore Day.
Honesdale,	1,000	. . .	. . .	. . .	[illegible]	76.0	29	27.0	3	63.8	43.7	20.1	37.0	6	[illegible]	8	. . .	. . .	2.98	12	. . .	. . .	. . .	. . .	John Torrey.
Greensburg,	1,075	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	H. S. Brunot.
York,	385	. . .	. . .	. . .	[illegible]	87.5	29	32.0	3	68.9	51.3	17.6	35.6	6	5.0	18	75.3	52.0	5.10	22	6	13	12	W	Mrs. L. H. Grenewald.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

* Observations taken at 8 A. M. and 8 P. M.

Day		Dyberry.	Honesdale.	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.	Stroudsburg	Coudersport.	Scisholtzville.	Germantown.	Frederick.	Ottsville.	Smith's Corner.	Point Pleasant.	Doylestown.	Lansdale.	Forks of Nesham'y.
1		·12	·24	·22	·17	·07	·03	·28	·10	·15	·11	·13	·20	·12	·13	·08	·13	·10
2		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
3		. .	·08	. .	. .	. .	. .	. .	. .	. .	. .	.	·05	. .	. .	. .	. .	. .
4		.	. .	·24	·11	. .	·02	·44	. .	·38	. .	. .	. .	. .	. .	. .	.	. .
5	7	·25	. .	. .	. .	. .	. .	. .	·10	. .	. .	·09	. .	·13	·14	. .	. .	·03
6		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
7		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
8		. .	·20	·13	. .	. .	. .	. .	. .	. .	. .	. .	·05	. .	. .	. .	. .	. .
9	2	·19	. .	·10	·10	·11	·04	·25	·70	·17	. .	·03	·11	. .	·17	. .	. .	. .
10	3	·35	. .	·08	·05	·02	·35	·20	. .	. .	. .	·04	. .	. .	. .	. .	. .	·21
11	7	. .	·19	·39	·57	·88	·71	·98	. .	. .	. .	. .	·99	. .	. .	1·02	. .	1·13
12	3	·28	. .	·18	·23	. .	·28	·30	·90	·79	·91	·37	·01	·94	. .	. .	·11	. .
13	2	. .	. .	. .	·06	·15	·07	. .	. .	. .	·20	·12	. .	·08	. .	. .	. .	·11
14	4	·20	·30	·01	·23	·17	·07	·33	. .	·24	·41	·11	·21	. .	. .	. .	·18	·05
15		. .	. .	. .	·01	. .	·02	. .	. .	. .	. .	·09	. .	·17	. .	. .	. .	. .
16	0	·52	·24	. .	·08	·04	·04	·01	·10	·05	. .	. .	. .	. .	. .	. .	. .	·05
17		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
18	3	. .	·50	. .	·10	. .	. .	. .	·20	·30	. .	. .	·33	. .	. .	. .	·31	. .
19	1	·53	·03	. .	·27	·02	·03	·70	·30	. .	·09	·46	. .	·37	1·72	·42	. .	·31
20		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
21		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
22		. .	.	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	·05	. .
23	4	. .	. .	. .	·07	·26	·25	. .	. .	. .	. .	. .	·09	. .	. .	. .	. .	. .
24	0	. .	·10	·10	·16	·19	·13	·18	·10	. .	. .	. .	·25	·11	. .	. .	. .	. .
25	8	·25	. .	·0	·03	·45	·55	·05	·20	. .	. .	·28	. .	·17	. .	. .	. .	·40
26	6	·10	·18	·11	·16	·05	·01	·06	. .	·60	·70	·23	·14	·12	·33	·51	·48	·06
27	2	. .	. .	·01	. .	. .	. .	. .	. .	. .	. .	·02	. .	. .	. .	. .	. .	. .
28		·15	·75	·65	·44	. .	·02	·25	·70	. .	. .	·03	·50	. .	. .	. .	. .	·32
29	6	·50	. .	. .	·08	.	·12	1·09	·40	·74	. .	·53	. .	·53	·50	·46	·43	. .
30	9	·15	. .	·09	·03	·30	·48	. .	. .	·09	1·87	·13	·19	·05	·15	·20	·60	·71
31	6	·27	·17	·01	·07	·31	·24	·01	. .	·09	·21	·05	. .	. .	·04	·06	·04	·02
	9	3·86	2·98	2·33	3·02	3·02	3·46	5·13	3·80	3·60	4·50	2·71	3·12	2·79	3·18	2·75	2·33	3·50

T. F. T.

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PRECIPITATION FOR MAY, 1888.

M[illegible]	Greenville.	New Castle.	Rochester.	Pittsburgh.	Columbus.	Clarion.	Uniontown.	Indiana.	Somerset.	Johnstown.	Grampian Hills.	Emporium.	Phillipsburg.	Hollidaysburg.	Altoona.
1	.01				.04	.03	.18	.31	.05	.05	.05	.01	.03		.01
2						.04		.03							
3															
4	.11	.10	.44	.29	.01		.51	.50	.88	.31		.06		.36	
5					.38	.33		.20	.23	.11	.53	.08	.50	.23	.45
6															
7			.07										.03		
8	[illegible]	.07	.05	.34	.22	.04	.33	.40	.20	.35		.05	.11	.67	
9	.25	.27	.04	.07	.28	.79	.29	.20	.22	1.11	.64	1.16	.36	1.26	.27
10					.07				.23	.29			.45	.76	.37
11	.04	.10		.02					.06						.37
12	[illegible]	.21	.19	.34	.04	.65	.28	.38	.50	.16	.88	.81	.18	.83	.08
13												.01	.32		.57
14	.31			.01			.21	.10	.15	.07	.10	.03	.05		.02
15			.14		.05								.05		
16		.04		.02	.15			.04	.20		.08	.08	.36		.03
17															
18	.13	.27	.72	.89	.39	.27	1.08	1.20	1.07	1.05	.70	.35	.21	1.38	.34
19				.15	.02	.13	.42	.08	.47	.20		.23	.43	.32	.75
20															
21															
22															
23	[illegible]	.06	.11	.05				.25		.17	.11	.16		.08	
24	[illegible]			.01	.02		.41	.13	.56	.19	.12	.08	.83	.18	.05
25	.43		.58	.71	.01		.11	.25	.15	.40	.10	.01	.26	.15	.07
26	[illegible]	.27	.06	.14	.05	.09	.05	.38	.18	.07	.24	.10	.14	.13	.27
27			.02										.07		
28	1.28	1.10	.90	.65	.68	1.03	.34	.80	.35	.10	.70	.93		.21	
29				.01	.08		.21	.05	.25	.01		.25	.57	.01	.43
30	.07			.04	.03										
31		.16		.39	.28	.06	.30		.10	.10	.33	.23	.01	.37	
	2.63	2.73	3.32	4.13	2.80	3.46	4.72	5.30	5.85	4.74	4.58	4.63	4.96	6.94	4.08

M[illegible]	Charlesville.	State College.	Huntingdon.	McConnellsburg.	Chambersburg.	Lock Haven.	New Bloomfield.	Carlisle.	York.	Wysox.	Eagles Mere.	Bernice.	Catawissa.	Shamokin.	Girardville.	Lebanon.
1	.04	.06			[illegible]	.10	.05	.10	.12		.16	.16	.19	.13		.35
2																
3																
4	.43	.25	.41	.22	[illegible]	.08	.60		.49	.07	.17		.28	.12	.34	.24
5	.62	.23		.23		.12		.28	.49			.14		.10		.05
6																
7																
8	.35	.13	.50	.33	.12	.24			.01	.25	.23	.16	.02		.22	.02
9	.66	.23	.20	.21	[illegible]	.10	.40	.20	.30	.06			.35	.23	.33	1.23
10	.05	1.21	1.0[illegible]	.08	[illegible]	.18	.90	.19	.30	.06	.07		.87	.36	.72	.05
11	.01				[illegible]	.17	.1[illegible]	.33	.0[illegible]	.02	.17	.09	.02	.63	.12	.06
12	.20	.44	.98	.92	[illegible]	.95	.60	.02	.88	.37	.22	.25	.16	.14	.27	.36
13								.80	.01							
14	.06	.08				.06		.01	.13	.03		.07			.19	.01
15									.01		.05	.06	.17	.35	.10	.15
16	.06	.07	.09	.13	.11	.07	.10	.10	.06	.10	.26	.14	.13	.20	.22	.10
17																
18	.59	.2[illegible]	.36	.47	.39	.04	.40	.20	.20	.02	.31	.15	1.20	.31	1.27	.22
19	.14	.80	1.38	.04		.01	.30	.22	.15			.10		.54		.12
20																
21																
22																
23	.54			.21	.16			.01	.13				.06	.05	.06	.03
24	.25	.96	.88	[illegible]	[illegible]	.40	1.00	1.10	.53		.03	.06	.12	.12	.08	.45
25	.15	.07	.11	.05	[illegible]		.10	.14	.04	.08	.46	.03	.01	.06	.09	.24
26	.16	.20	.43	.29	.13	.12	.10	.06	.15	.02		.05		.07	.12	.11
27								.01		.11	.10	.04		.02	.14	.05
28	.06	1.21	1.89	.37	[illegible]	1.06	1.20	.03	.01	.63	1.26	.60	1.55	1.55	2.72	.71
29	.03		.04	[illegible]		.02	.30	.76	.35			.39		1.05		.22
30	.06	.06		.39			.10		.03	.06	.03					.03
31	.37	.04	.14	.45	[illegible]	.15	.30	.58	.69	.37	.18	.07	.07	.08	.09	.28
	4.83	6.26	8.41	4.7[illegible]	[illegible].55	3.87	6.55	5.14	5.10	2.31	3.70	2.55	5.20	6.11	7.08	5.08

M[illegible]	Lancaster.	Montrose.	Drifton.	Scranton.	Reading.	Kutztown.	Pottstown.	West Chester.	Coatesville.	Dyberry.	Honesdale.	Bethlehem.	Quakertown.
1	.10	.20	.54	.22	.22	.25	.15	.24	.10	.12	.24	.22	.17
2													
3											.08		
4							.20	.02	.01			.24	.11
5	.23	.14		.08	.48	.25			.07	.25			
6													
7													
8	.01	.14		.09							.20	.13	
9	.24	.15		.13		.20	.07	.02	.02	.19		.10	.10
10	.10		.3[illegible]	.04			.10	.04	.03	.33		.08	.05
11	.15	.17	.68	.11	.30	.35	.50	.44	.37		.19	.39	.57
12	.34	.23	.17	.08	.27	.23	.40	.34	.33	.28		.18	.23
13	.02			.06				.10	.0[illegible]				.06
14	.08	.01	.10	.30			.35	.07	.14	.20	.30	.01	.23
15	.01			.20				.02					.01
16	.09	.18	.21	.12	.08	.12		.12	.10	.52	.24		.08
17													
18	.40	.21	.26	.16	.16	.31	.50	.06	.08		.50		.10
19			.91	.11	.20			.03	.01	.53	.03		.27
20													
21													
22													
23	.13				.12	.07		.21	.14				.07
24	.30		.25	.02	.18		.40	.40	.4[illegible]		.10	.10	.16
25	.17	.02	.26	.01	.05	.17	.30	.26	[illegible]	.25		.0[illegible]	.03
26		.08	.17	.19	.07	.21	.10	.03	.06	.10	.18	.11	.16
27	.13							.01	.02			.01	
28	.05	.22	.12	.34	1.20	.51	1.00	.01		.13	.75	.65	.44
29	.55	.88	1.72	.75	.11	.26		.19	.4[illegible]	.50			.08
30	.24	.03			.13	.04	.03	1.19	.2[illegible]	.15		.09	.03
31	.05	.37		.12	.26	.12	.15	.25	.16	.27	.17	.01	.07
	3.33	3.03	5.63	3.13	3.83	3.11	4.25	4.11	2.8[illegible]	3.86	2.98	2.33	3.02

M[illegible]	Swarthmore.	Philadelphia.	Stroudsburg.	Coudersport.	Scisholtzville.	Germantown.	Frederick.	Ottsville.	Smith's Corner.	Point Pleasant.	Doylestown.	Lansdale.	Forks of Nesham'y.
1	.07	.03	.28	.10	.15	.11	.13	.20	.12	.13	.08	.13	.10
2													
3								.05					
4		.02	.44		.38								
5				.10			.09		.13	.14			.03
6													
7													
8								.05					
9	.11	.04	.25	.70	.17		.03	.11		.17			
10	.02	.35	.20				.04						.21
11	.88	.71	.98					.99			1.02		1.13
12		.28	.30	.90	.79	.91	.37	.01	.94			.11	
13	.15	.07				.20	.12		.08				.11
14	.17	.07	.33		.24	.41	.11	.31				.18	.05
15		.02					.09		.17				
16	.04	.04	.01	.10	.05								.05
17													
18				.20	.30			.33				.31	
19	.02	.03	.70	.30		.09	.46		.37	1.72	.42		.31
20													
21													
22												.05	
23	.26	.25						[illegible]					
24	.19	.13	.18	.10				.25	.11				
25	.45	.55	.05	.20			.28		.17				.10
26	.05	.01	.06		.60	.70	.23	.14	.12	.33	.51	.48	.06
27							.02						
28		.02	.25	.70			.03	.50					.32
29		.12	1.09	.40	.74		.53		.53	.50	.46	.43	
30	.30	.48			.0[illegible]	1.87	.13	.19	.05	.15	.20	.60	.71
31	.31	.24	.01		.09	.21	.05			.01	.06	.04	.02
	3.02	3.46	5.13	3.80	3.60	4.50	2.71	3.12	2.79	3.18	2.75	2.33	3.50

T. F. T.

PENNSYLVANIA STATE WEATHER SERVICE.

MONTHLY WEATHER REVIEW

FOR JUNE, 1888.

Prepared under the Direction of the Committee on Meteorology of the FRANKLIN INSTITUTE.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 30, 1888.

TEMPERATURE.

The mean temperature for June, 1888, as deduced from the observations of more than fifty stations, gives 68°·6, which is probably 1° above the average.

The departures from the June normals (fifteen years) at the Signal Service Stations show the following: Erie, 0°·0; Pittsburgh + 1°·0; Philadelphia, + 1°·5. The mean of the daily maximums at fifty stations, 80°·7, and the mean of the daily minimums, 56°·1, give an average, or mean, of 68°·4, which very nearly corresponds with that determined from the tri-daily readings.

The highest temperatures prevailed on the 21st, but they were not unusual for the season. The highest June temperatures for the past fifteen years give an average at Erie, Pittsburgh and Philadelphia of 87°·7, 94°·0 and 92°·5, respectively, against 87°·5, 95°·2 and 97°·2 during June, 1888. Lock Haven reports 100°; Chambersburg, 99°·5; Reading, 99°; Catawissa, 99°; Carlisle, 99°, and Montrose, 99°.

The lowest temperatures noted were Coudersport, 30°; Somerset, 31°; Columbus, 32°; Dyberry, 32°, and Honesdale, 32°. Most of the low temperatures occurred on the 4th, with frosts at many places. At the close of June, the season was less than one week late.

ATMOSPHERIC PRESSURE.

The barometer was normal with slight fluctuations, ranging but little over half an inch.

PRECIPITATION.

There was a rainfall deficiency of about one inch. The total average throughout the State was 3·04 inches, but, owing to its unequal distribution, several sections had a large deficiency, and a few an excess, caused by heavy local storms. In many parts rain was needed during the first three weeks of the month, but copious showers fell in all districts during the last week, which favorably affected all growing crops. The extremes of rainfall reported were: Coudersport, 6·90 inches; Emporium, 6·57 inches; Girardville, 6·50 inches; Pottstown, 1·55 inches; Bernice, 1·15 inches; Phillipsburg, 1·11 inches, and Philadelphia, 1·08 inches.

Average number.—Rainy days, 9; clear days, 12; fair days, 11; cloudy days, 7.

Prevailing direction of wind, 7 A. M., northwest; 2 P. M., southwest; 9 P. M., southwest.

MISCELLANEOUS PHENOMENA.

Thunder Storms.—Rochester, 9th, 10th, 14th; Charlesville, 6th, 9th, 10th, 14th, 16th, 18th, 21st, 22d, 23d; Reading, 10th, 18th, 21st, 22d, 23d; Kutztown, 10th, 14th, 15th, 16th, 18th, 21st, 23d; Johnstown, 6th, 10th, 14th, 15th, 20th, 21st, 23d, 24th; Emporium, 2d, 10th, 14th, 15th, 21st, 23d, 24th; State College, 21st; West Chester, 16th, 23d; Coatesville, 14th, 16th, 21st, 23d; Clarion, 6th, 14th, 15th, 21st, 22d, 23d; Grampian Hills, 2d, 11th, 23d, 24th, 28th; Catawissa, 21st, 23d, 24th; Carlisle, 10th, 14th, 15th, 16th, 21st, 23d; Swarthmore, 16th, 23d; Erie, 2d, 10th, 14th, 15th, 21st, 22d, 23d; Uniontown, 6th, 14th, 22d, 24th, 26th, 29th; Tionesta, 15th; McConnellsburg, 21st; Huntingdon, 24th; Indiana, 2d, 6th, 10th, 15th, 21st, 24th, 27th, 28th; Scranton, 2d, 15th, 21st, 23d, 24th; Lancaster, 16th, 23d, 28th; New Castle, 9th, 10th, 14th; Lebanon, 10th, 23d; Drifton, 21st, 23d; Greenville, 10th, 14th, 15th, 22d, 23d, 24th; Stroudsburg, 14th, 15th, 23d, 24th; Bethlehem, 10th, 14th, 15th, 16th, 18th, 21st, 23d; Shamokin, 24th; New Bloomfield, 15th, 16th, 21st, 23d; Philadelphia, 16th, 23d; Blooming Grove, 15th, 18th, 23d, 24th, 30th; Coudersport, 6th, 10th, 14th, 15th, 16th, 21st, 22d, 23d, 24th; Girardville, 21st, 23d, 24th; Somerset, 15th, 21st, 24th; Eagles Mere, 10th, 14th, 15th, 21st, 23d; Bernice, 7th, 15th, 21st, 22d, 23d, 26th; Montrose, 6th, 23d, 24th; Wellsboro, 2d, 10th, 14th, 15th, 21st, 22d, 23d, 24th; Franklin, 14th, 15th, 21st, 22d, 23d, 24th; Columbus, 10th, 14th, 21st, 22d, 23d, 24th; Dyberry, 15th, 24th, 30th.

Hail.—Quakertown, 16th; Johnstown, 6th; Coatesville, 16th; Carlisle, 23d; Tionesta, 15th; Scranton, 15th; Greenville, 2d; New Bloomfield, 16th; Blooming Grove, 15th; Coudersport, 2d; Franklin, 15th.

Frosts.—Pittsburgh, 4th; Rochester, 4th; Charlesville, 3d; Wysox, 4th; Johnstown, 4th; Coatesville, 4th; Grampian Hills, 4th; Catawissa, 4th;

Tionesta, 4th; Scranton, 4th; New Castle, 4th; Greenville, 12th; Coudersport, 2d, 4th, 5th, 12th; Somerset, 3d, 4th, 12th; Eagles Mere, 4th; Montrose, 4th; Wellsboro, 2d, 3d, 4th, 5th, 12th; Franklin, 4th; Dyberry, 4th, 5th; York, 4th; Uniontown, 3d, 4th.

Auroras.—Reading, 3d; Quakertown, 1st; State College, 3d; Coatesville, 1st; Clarion, 3d; Greenville, 7th, 10th; New Bloomfield, 6th; Eagles Mere, 5th, 27th; Bernice, 3d; Wellsboro, 12th.

Coronæ.—Rochester, 13th, 14th; Reading, 22d; Lebanon, 13th, 14th, 15th, 19th, 20th, 21st, 22d, 24th; Greenville, 13th; Somerset, 19th, 26th; Eagles Mere, 12th; Dyberry, 12th, 14th, 19th.

Solar Halos.—Charlesville, 4th, 6th, 7th, 8th, 9th, 12th, 13th, 15th, 20th; Eagles Mere, 27th; Wellsboro, 27th; Dyberry, 13th.

Lunar Halos.—Rochester, 16th; Phillipsburg, 20th, 21st; Carlisle, 13th, 14th; Somerset, 19th, 22d.

T. F. T.

WEATHER SIGNALS.

Displayman.	*Station.*
U. S. Signal Office,	Philadelphia.
Wanamaker & Brown,	"
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Samuel Simpson,	"
B. T. Babbitt,	"
Western Meat Company,	"
Neptune Laundry,	"
Chester Oil Company,	Chester.
C. W. Burkhart,	Shoemakerville.
A. N. Lindenmuth,	Allentown.
C. B. Whitehead,	Bradford.
Capt. Geo. R. Guss,	West Chester.
Werner & Son,	Emporium.
C. E. Lenhart,	Latrobe.
Thomas F. Sloan,	McConnellsburg.
J. H. Fulmer,	Muncy.
W. T. Butz,	New Castle.
S. W. Morrison,	Oxford.
Capt. A. Goldsmith,	Quakertown.
J. L. Morrison,	Sharon.
Wm. A. Engel,	Shenandoah.
Wm. Schrock,	Somerset.
Postmaster,	Meadville.
Frank Ross,	Oil City.
Lerch & Rice,	Bethlehem.
John W. Aitken,	Carbondale.
Signal Office,	Erie.
J. R. Raynsford,	Montrose.

Displayman.	*Station.*
E. P. Wilbur & Co.,	South Bethlehem.
Agricultural Experiment Station,	State College.
Signal Office,	Pittsburgh.
E. H. Baker,	Williamsport.
New Era,	Lancaster.
State Normal School,	Clarion.
Clarion Collegiate Institute,	Rimersburg.
E. S. Chase,	Eagles Mere.
Thiel College,	Greenville.
D. G. Hurley,	Altoona.
Armstrong & Brownell,	Smethport.
J. E. Forsythe,	Butler.
James H. Fones,	Tionesta.
Wister, Hacker & Savage,	Germantown.
W. J. Thompson & Co.,	Clifton Heights.
Steward M. Dreher,	Stroudsburg.
State Normal School,	Millersville.
E. C. Wagner,	Girardville.
Hartford P. Brown,	Rochester.
L. H. Grenewald,	York.
J. E. Pague,	Carlisle.
C. L. Peck,	Coudersport.
H. D. Miller,	Drifton.
—— Curtis,	Beaver.

NIA STATE

Date.	Relative Humidity.
29	63·7
29	86·6
28	75·1
. . .	. . .
7	. . .
29	54·1
28	81·0
28	74·9
28	77·9
. . .	. . .
29	70·8
29	64·0
7	70·6
30	. . .
29	65·0
29	. . .
. . .	. . .
26	75·6
7	. . .
7	. . .
28	68·7
. . .	. . .
28	83·7
29	70·4
. . .	. . .
28	67·0
29	78·5
2	80·0
28	. . .
28	73·7
30	81·9
28	79·2
26	76·0
29	78·8
29	76·6
28	77·5
30	. . .
. . .	. . .
28	. . .
29	81·2
26	84·0
29	70·0
1	72·0
29	68·0
28	. . .
29	63·1
. . .	. . .
28	72·1
. . .	. . .
. . .	. . .
29	80·0
28	67·0
26, 29	77·3
17	. . .
23	71·6
. . .	74·0
. . .	. . .
. . .	. . .
9, 29	76·7
28	. . .
7	. . .
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11	70·7

	Lansdale.	Forks of Nesham'y.
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. F. T.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for June, 1888.

County.	Station.	Elevation above Sea Level (feet).	Barometer. Mean.	Barometer. Highest.	Barometer. Lowest.	Temperature. Mean.	Temperature. Maximum. Highest.	Temperature. Maximum. Date.	Temperature. Minimum. Lowest.	Temperature. Minimum. Date.	Temperature. Mean of Maximum.	Temperature. Mean of Minimum.	Temperature. Daily Range. Mean.	Temperature. Daily Range. Greatest.	Temperature. Daily Range. Date.	Temperature. Daily Range. Least.	Temperature. Daily Range. Date.	Relative Humidity.	Dew Point.	Precipitation. Total Inches.	Precipitation. Number of Days Rainfall.	Number of Days. Clear.	Number of Days. Fair.	Number of Days. Cloudy.	Wind. Prevailing Direction. 7 A. M.	Wind. Prevailing Direction. 2 P. M.	Wind. Prevailing Direction. 9 P. M.	Observers.
Allegheny,	Pittsburgh,	847	29·936	30·240	29·720	7[illegible]	95·2	20	41·4	3	82·4	61·4	21·0	30·7	5, 20	9·3	29	63·7	57·6	2·22	11	5	18	7	NW	NW	NW	Oscar D. Stewart, Sgt. Sig. Corps.
Beaver,	Rochester,	821	...	...	...	[illegible]	94·0	20, 21	37·0	4	81·2	56·5	24·7	37·0	5, 20	8·0	29	86·6	63·6	2·51	5	12	12	6	NW	NW	o	Hartford P. Brown, Jr.
Bedford,	Charlesville,	1,300	...	...	...	[illegible]	93·5	21	[illegible]	3	79·6	53·2	26·4	42·5	5	5·0	28	75·1	58·4	3·00	11	10	5	5	W	W	SW	Rev. A. Thos. G. Apple.
Berks,	Reading,	292	...	...	...	7[illegible]	99·0	21	51·7	29	...	...	...	...	...	...	...	...	...	3·33	9	12	10	8	NW	NW	S	C. M. Dechant, C.E.
Berks,	Kutztown— Keystone State Normal School,	540	...	...	...	[illegible]	94·5	18	52·0	29	80·5	63·1	17·4	26·2	20	4·5	7	...	...	4·25	6	17	6	7	...	...	...	Prof. J. H. Rohrbach.
Blair,[1]	Altoona,	1,181	30·180	30·420	30·000	7	97·0	23, 24	41·0	3	83·2	59·5	23·7	34·0	7	14·0	29	54·1	63·0	2·38	11	...	...	...	...	...	...	Dr. Charles B. Dudley.
Blair,	Hollidaysburg,	947	...	...	...	7	98·0	20, 21	35·0	3, 4	84·0	53·1	30·9	40·0	5	9·0	28	81·0	64·0	2·31	11	15	13	2	E	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,	718	...	...	...	[illegible]	93·5	23	35·5	4	80·2	54·3	25·9	38·6	5	11·3	28	74·9	58·2	2·75	7	9	8	13	NE	NW	NW	Charles Beecher.
Bucks,	Quakertown,	536	29·940	30·310	29·740	6[illegible]	97·0	23	41·5	2	82·0	54·8	27·2	38·5	20	14·5	28	77·9	61·7	1·85	9	15	11	4	NE	SW	NW	J. L. Heacock.
Butler,	Butler,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. E. Forsythe.
Cambria,	Johnstown,	1,184	...	...	...	[illegible]	96·0	19, 20	38·0	4	83·9	56·9	27·0	40·0	19	7·0	29	70·8	57·7	3·73	14	12	11	7	SW	SW	SW	E. C. Lorentz.
Cameron,	Emporium,	1,030	...	...	...	7	96·0	21	35·0	4	82·4	52·7	29·7	44·0	5	11·0	29	64·0	58·5	6·57	10	14	10	6	SW	SW	NW	T. B. Lloyd.
Centre,	State College— Agricultural Experiment Station,	1,191	29·964	30·320	29·683	[illegible]	95·0	21	38·5	4	78·6	56·1	22·5	35·0	4	8·0	7	70·6	59·4	2·61	7	10	14	6	W	W	W	Prof. Wm. Frear.
Centre,	Phillipsburg,	1,350	...	...	...	[illegible]	95·0	21	35·0	3	87·0	42·5	44·5	40·0	15	8·0	30	...	...	1·11	6	18	9	1	SW	SW	SW	I. Ray Morgan.
Chester,	West Chester,	455	29·942	30·245	29·715	7	94·5	23	49·0	3, 4	80·7	60·5	20·2	29·0	6	9·0	29	65·0	58·4	1·70	11	21	2	7	NW	SW	NW	Jesse C. Green, D.D.S.
Chester,	Coatesville,	380	...	...	...	[illegible]	97·0	23	43·0	2, 4	82·8	56·5	26·3	37·5	6	10·5	29	...	...	1·70	7	15	10	5	S	S	S	W. T. Gordon.
Clarion,	Rimersburg,	1,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Rev. W. W. Deatrick, A.M.
Clarion,	Clarion— State Normal School,	1,530	...	...	...	[illegible]	[illegible]	21	34·0	4	79·2	53·5	25·7	39·0	8	[illegible]	26	75·6	57·3	...	11	12	12	6	SW	S	SW	C. M. Thomas, B.S.
Clearfield,	Grampian Hills,	1,450	...	...	...	[illegible]	94·0	18	38·0	4	78·4	57·4	21·0	34·0	12	4·0	7	...	...	2·30	9	10	9	11	W	SW	W	Nathan Moore.
Clinton,	Lock Haven,	560	...	...	...	[illegible]	[illegible]	21	41·0	2	82·0	54·8	27·2	41·0	5	5·0	7	...	...	2·00	6	17	10	3	W	W	W	Prof. John A. Robb.
Columbia,	Catawissa,	491	...	...	...	7	99·0	21	40·0	4	83·5	59·3	24·2	38·0	17	5·0	28	68·7	64·2	2·78	8	13	14	3	E	NW	NW	Robert M. Graham.
Crawford,	Meadville— Allegheny College,	1,050	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. J. H. Montgomery.
Cumberland,	Carlisle,	480	...	...	...	7	99·0	21	51·5	3	82·9	63·8	19·1	31·5	5	5·8	28	83·7	66·3	3·25	10	14	14	2	W	W	o	J. E. Pague.
Delaware,	Swarthmore— Swarthmore College,	[illegible]	29·941	30·227	29·730	7	95·7	23	47·8	2	81·3	59·8	21·5	32·1	20	10·2	29	70·[illegible]	60·0	1·32	1	9	10	11	NW	NW	...	Prof. Susan J. Cunningham.
Elk,	Ridgway,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Joe Messinger.
Erie,	Erie,	681	29·940	30·250	29·620	[illegible]	87·5	9	43·7	8	74·8	58·6	16·2	29·0	5	8·1	28	67·0	55·0	2·38	11	9	16	5	S	S	S	Peter Wood, Sgt. Sig. Corps.
Fayette,	Uniontown,	1,000	29·938	30·191	29·710	[illegible]	90·0	20	38·0	4	80·5	60·9	19·6	37·0	5	5·0	29	78·5	64·8	4·65	12	19	5	6	SW	SW	SW	Wm. Hunt.
Forest,	Tionesta,	1,058	...	...	...	[illegible]	93·0	21	35·0	4	81·4	67·8	13·6	30·0	5	15·0	2	80·0	57·0	...	7	...	...	...	S	S	S	Robert L. Haslet.
Franklin,[3]	Chambersburg— Wilson Female College,	618	29·973	30·230	29·81[illegible]	[illegible]	99·5	22	41·0	4	83·3	54·7	28·6	46·0	14	9·0	28	...	...	2·37	5	11	10	9	...	...	...	Miss Mary A. Ricker.
Fulton,	McConnellsburg,	875	...	...	...	6[illegible]	97·0	18, 21	40·0	4, 5	82·8	55·6	27·2	38·0	6	7·0	28	73·7	60·0	3·10	8	15	11	4	NW	W	NW	Thomas F. Sloan.
Huntingdon,	Huntingdon— The Normal College,	650	...	...	...	...	98·9	21	36·0	3	84·0	51·1	32·9	42·5	5	11·0	30	81·9	62·2	2·85	6	13	11	6	W	W	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	94·0	22	35·0	3, 4	80·5	54·9	25·6	37·0	4, 9	5·0	28	79·2	61·1	4·65	11	10	13	7	SW	W	SW	Prof. Albert E. Maltby.
Lackawanna,	Scranton,	750	...	...	...	6	96·5	21	38·0	4	81·8	55·9	25·9	39·0	5	14·0	20	76·0	61·4	2·75	10	12	14	4	NW	W	NW	T. F. Heebner, M.D.
Lancaster,	Lancaster— Franklin and Marshall College,	413	29·949	30·253	29·747	[illegible]	97·0	23	41·1	4	80·2	55·6	24·6	35·1	3	14·0	29	78·8	67·2	2·56	5	9	14	7	W	W	W	A. M. Schmidt, A.B.
Lawrence,	New Castle,	932	...	...	...	...	95·0	22	33·0	4	82·6	54·4	28·2	43·0	5	8·0	29	76·6	62·1	3·25	11	10	11	9	SE	SW	N	Wm. T. Butz.
Lebanon,	Lebanon,	480	29·981	30·293	29·755	...	96·4	23	39·5	4	81·6	56·4	25·2	36·7	20	13·0	28	77·5	62·2	2·57	10	15	11	4	SW	SW	SW	George W. Hayes, C.E., Ph.G.
Luzerne,	Drifton— Drifton Hospital,	1,655	...	...	...	...	97·0	21	38·0	3	81·3	55·8	25·5	39·0	20	11·0	30	...	...	4·18	4	...	...	...	NW	W	NW	H. D. Miller, M.D. E. H. Baker.
Lycoming,	Williamsport,	525	...	...	...	...	92·0	21	34·0	2	76·7	48·8	27·9	43·0	8	3·0	28	...	...	5·02	10	10	13	7	S	W	SW	Armstrong & Brownell.
McKean,	Smethport,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
Mercer,	Greenville— Thiel College,	1,000	29·867	30·124	29·659	[illegible]	94·0	22	35·0	4	79·5	52·3	27·2	41·0	22	9·2	29	81·2	63·2	3·44	15	4	15	11	SW	W	N	Prof. S. H. Miller.
Monroe,	Stroudsburg,	430	...	...	...	[illegible]	94·0	23	36·0	4	82·3	53·4	28·9	40·0	5	10·0	26	84·0	63·0	3·11	9	5	21	4	SW	SW	SW	N. C. Miller, M.D.
Montgomery,	Pottstown,	150	...	...	...	7	98·0	28	50·0	12	83·2	64·9	18·3	30·0	5	8·0	29	70·0	62·4	1·55	3	18	8	4	W	W	W	Charles Moore, D.D.S.
Northampton,	Bethlehem,	360	29·916	30·180	29·668	7[illegible]	95·0	18	43·0	4	83·0	57·0	26·0	36·0	6	14·0	1	72·0	61·0	3·12	8	13	12	6	W	W	W	Lerch & Rice.
Northumberland,[2]	Shamokin,	733	...	...	...	[illegible]	82·0	24	36·0	4	81·0	54·0	27·0	39·0	17	14·0	29	68·0	57·0	1·88	5	11	10	4	W	W	o	G. R. Hanley.
Perry,	New Bloomfield,	400	...	...	...	[illegible]	98·0	21	38·0	4	81·5	55·0	26·5	41·0	20	9·0	28	...	...	3·50	9	16	9	5	N	N	W	Frank Mortimer.
Philadelphia,	Philadelphia,	117	29·949	30·250	29·720	7[illegible]	97·2	23	52·2	29	83·5	63·2	20·3	27·4	14	10·8	29	63·1	58·2	1·08	5	8	17	5	S	W	S	Luther M. Dey, Sgt. Sig. Corps.
Pike,	Blooming Grove,	800	...	...	...	[illegible]	98·0	22	48·0	3	...	...	...	...	...	...	...	...	...	3·50	7	...	...	...	...	...	...	John Grathwohl.
Potter,	Coudersport,	...	...	...	...	[illegible]	94·0	21	30·0	4	77·3	50·7	26·6	43·0	9	7·0	28	72·1	58·5	6·90	12	16	2	12	W	W	...	D. W. Butterworth.
Schuylkill,	Girardville,	1,000	29·965	30·265	29·758	[illegible]	92·0	21	50·0	3	79·2	59·0	20·2	...	...	...	...	...	...	6·50	8	12	6	12	NW	W	NW	E. C. Wagner.
Snyder,	Selins Grove,	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	J. M. Boyer.
Somerset,	Somerset,	2,250	...	...	...	[illegible]	92·0	20	31·0	3	79·1	53·2	25·9	43·5	5	10·0	29	80·0	58·3	2·76	11	12	9	9	NW	W	SW	W. M. Schrock.
Sullivan,	Eagles Mere,	2,060	29·945	30·330	29·470	[illegible]	86·0	21	30·0	3	71·7	54·5	17·2	26·0	14	5·0	28	67·0	54·0	2·69	9	6	13	6	SW	W	SW	E. S. Chase.
Sullivan,[1]	Bernice,	2,000	30·133	30·347	29·908	[illegible]	91·0	21	37·0	2	72·8	52·3	20·5	33·0	20	13·0	[illegible], 29	77·3	58·1	1·15	10	9	13	6	W	W	SW	C. R. Claghorn.
Susquehanna,	Montrose,	1,656	...	...	...	[illegible]	99·0	21	45·0	4	74·0	60·2	13·8	28·0	8	4·0	17	...	...	1·16	7	15	5	10	NW	W	N	A. H. Berlin.
Tioga,	Wellsboro,	1,327	29·891	30·286	29·606	[illegible]	94·0	21	35·0	5	79·6	54·5	25·1	18·2	5	4·2	23	71·6	65·1	1·90	13	8	10	12	N	N	N	H. D. Deming.
Venango,	Franklin,	1,000	...	...	...	[illegible]	91·8	22	42·0	4	...	...	...	...	...	...	...	74·0	57·0	6·53	13	5	16	9	W	W	NW	Prof. N. P. Kinsley.
Washington,	Scenery Hill,	1,750	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Jacob Gayman.
Washington,	Washington,	1,175	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Harrison Otis.
Warren,	Columbus,	1,410	...	...	...	[illegible]	98·0	20	32·0	4	79·4	51·4	28·0	52·0	17	9·0	9, 29	76·7	55·6	4·38	14	11	9	7	SW	W	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	[illegible]	91·0	[illegible]	32·0	4	70·7	50·1	26·6	42·0	5	11·0	28	...	...	2·07	10	9	15	6	NW	W	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	[illegible]	89·0	23	32·0	4	75·5	51·0	23·6	35·0	4, 5	7·0	7	...	...	2·39	8	...	...	...	...	...	...	John Torrey.
Westmoreland,	Greensburg,	1,075	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	H. S. Brunot.
York,	York,	385	...	...	...	[illegible]	98·0	21	41·0	4	81·0	57·1	25·9	43·0	21	11·0	11	70·7	60·5	2·23	9	20	8	2	NW	W	NW	Mrs. L. H. Grenewald.

T. F. Townsend, *Sergeant Signal Corps, Assistant.*

[1] 26 days. [2] 25 days. [3] Observations taken at 8 A. M. and 8 P. M. [4] Observations taken at 12 Noon.

Erie.	Greenville.	New Castle.	Rochester.	Pittsburgh.		West Chester.	Coatesville.	Dyberry.	Honesdale.	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.	Coudersport.	Scisholtzville.	Frederick.	Ottsville.	Germantown.	Smith's Corner.	Point Pleasant.	Doylestown.	Lansdale.	Forks of Nesham'y.
. .	. .	'20	. .	. .		'02	. .	. .	. .	. .	. .	. .	. .	'10	. .	. .	. .	. .	. .	'01	. .	'06	. .
'03	'04	. .	. .	'25		'08	'01	'05	'08	. .	'07	. .	. .	'10	. .	'04	. .	. .	'05	. .	'10	. .	'01
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. .	'09	'11	. .	'01		. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
'24	'53	. .	'62	'01		'09	. .	'17	. .	'01	'08	. .	. .	'60	'17	. .	'16	. .	'12	'02	. .	. .	. .
. .	'01	'75	'22	'04	8	'03	. .	. .	'06	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
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'12	'13	'53	. .	. .		. .	. .	'03	. .	'16	'08	. .	. .	'60	. .	'05	. .	. .	'05	. .	. .	. .	. .
'08	'05	. .	. .	. .		. .	. .	'40	'92	'03	. .	. .	. .	. .	. .	'04	'19	. .	'24	. .	'19	'26	'45
. .	. .	. .	. .	. .		'07	'48	. .	. .	. .	'30	. .	'06	'90	. .	'04	. .	'15	'54	1'11	'13	. .	'25
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. .	'06	. .	. .	'33		. .	. .	. .	. .	. .	. .	. .	. .	'70	. .	. .	. .	. .	. .	. .	. .	. .	. .
'36	'95	'08	. .	'17		. .	'05	'04	'01	'85	. .	. .	'21	'50	'14	. .	. .	'34	. .	. .	. .	'59	1'70
'01	'61	'12	'23	'10		. .	. .	. .	'21	. .	'01	'02	. .	1'10	. .	. .	. .	. .	. .	. .	. .	. .	. .
'20	'01	'12	. .	. .		. .	. .	'56	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
'25	'02	'10	. .	. .		'05	. .	'22	'12	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
. .	'15	. .	'48	'12		1'25	'04	. .	. .	. .	. .	. .	'02	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
1'09	'76	1'10	'96	1'10	o	'14	1'09	'30	'29	1'03	1'00	1'23	'76	'80	. .	. .	. .	. .	. .	. .	1'11	'77	. .
. .	'02	'12	. .	'08	7	'02	'06	'03	. .	. .	'08	'07	'03	'80	1'35	1'06	'88	1'06	'69	'86	. .	. .	1'00
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2'38	3'44	3'25	2'51	2'22	5	1'79	1'76	2'07	2'39	3'12	1'85	1'32	1'08	6'90	1'79	1'45	1'23	1'55	1'69	2'00	1'53	2'10	3'41

T. F. T.

PRECIPITATION FOR JUNE, 1888.

[illegible]	New Castle	Rochester	Pittsburgh.	Columbus.	Uniontown.	Indiana.	Somerset.	Johnstown.	Grampian Hills	Emporium.	Phillipsburg.	Hollidaysburg.	Smethport.	Altoona.	Charlesville.	State College.	Huntingdon.	McConnellsburg.	Chambersburg.	Lock Haven.	New Bl[illegible]	Wellsboro.	Carlisle.	York.	Wysox.	Eagles Mere.	Bernice.	Catawissa.	Shamokin.	Girardville.	Lebanon.	Lancaster	Drifton.	Scranton.	Reading	Kutztown.	Pott[illegible]	West Chester.	Coatesville.	Dyberry.	Honesdale.	Bethlehem.	Quakertown.	Swarthmore.	Philadelphia.	Coudersport.	Scisholtzville	Frederick	Ottsville.	Germantown.	Smith's Corner.	Point Pleasant.	Doylestown.	Lansdale.	Forks of Nesham'y.
	·10				·12									·03								20	·03				·07								·12			·02								·10						·01		·06	
			·25	·38	·22	1·00		·27	·23	·05	·01	·17	·04	·05	·03	·30	·23	·02	·14	·01	·10	·10	·02	·03	·07	·02	·06	·06	·08	·12	·03	·03						·08	·01	·05	·08		·07			·10		·04			·05		·10		·01
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·1		·62	·01	·45		·40		·05	·43	·76			·62		·19			·12			·01	·08		·01	·12	·11		·02			·36	·03		·24	·08			·09		·17		·01	·08			·60	·17		·16		·12	·02			
	·75	·22	·04	·02	·50	·05	·23	·17				·02		·35	·09	·20	·12	·03		·01			·09				·25				·01			·02			8	·03			·06														
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·12	·53			·44	·86	·02	·13	·37	·03	·78			·30									·18	·01	·17		·36								·37						·03		·16	·08			·60		·05			·05				
5				·01		·62		·25		·15		·31	·25	·05	·12							·12	·20		·57	·04	·40			·08	·02			·73						·40	·92	·03						·04	·19		·24		·19	·26	[illegible]
													·17																		·02	·10			·27	·05		·07	·48				·30		·06	·90		·04		·15	·54	1·11	·13		·25
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			·33	·01	1·10		·75	·02			·04	·33	1·50	·30	·83			·19	·26			·05	·16			·15	·02						·52		·19											·70									
	·08		·17	·52	·48		·05	·25		1·50		·10				·62		·04		[illegible]	[illegible]	1·24		·47	·22	·91	·05	·27		1·56	·32	·83	1·80	·13	·66	1·86			·05	·04	·01	·85			·21	·50	·14			·34				·50	1·70
	·12	·23	·10	·95	·02	·37	·25	·25	·30	·32	·32	·05	1·06	·74			·62			[illegible]	[illegible]	·70	1·00	·17	·90	·34	·22	·70	1·42	·58			1·26	·43							·21		·01	·02		1·10									
	12			·12										·15		·04																		·25						·56															
	·10			·08	·31	·04	·04		·10	·13			·23		·01							·12			·48						·03			·19						·22	·12														
		·48	·12		·41	·60	·25	·17	·25		·55	·23		·04	·25	·78	·38	·35	·02					·04	·26	·68		·25	·18	·43	·08							1·25	·04						·02										
	1·10	·96	1·10	1·00	·03	·40	·73	·37	·82	·80		·51	·75	·54	·72		·30	·70	·98	[illegible]	·92	·94	1·28	·03	·13		·03	·23	·05	1·20	1·56	1·57	·60	·19	1·10	1·80	[illegible]	·14	1·09	·30	·29	1·03	1·00	1·23	·76	·80							1·11	·77	
	12		·08	·07	·50		·07	·11				·55		·01	·21		1·20			[illegible]	·90	·05	45	·04			·02	·07	·15	·18	·14				·25	·04	[illegible]	[illegible]	·06	·03			·08	·07	·03	·80	1·35	1·06	·88	1·06	·69	·86			1·00
																																		·20						·27	·70														
	·25	2·51	2·22	4·38	4·65	4·60	2·76	3·73	2·30	6·57	1·11	2·31	5·02	2·38	3·00	2·61	2·85	3·10	2·37	2·[illegible]	[illegible]	3·00	3·25	2·23	2·75	2·69	1·15	2·78	1·88	6·50	2·57	2·56	4·18	2·75	2·61	4·25	[illegible]	1·79	1·76	2·07	2·39	3·12	1·85	1·32	1·08	6·90	1·79	1·45	1·23	1·55	1·69	2·01	1·53	2·10	3·41